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National Electric Light Association

Forty-Second Convention

Technical Section Sessions

PAPERS, REPORTS and DISCUSSIONS

Proceedings

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TECHNICAL AND HYDRO-ELECTRIC SECTION

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THIRD SESSION—WEDNESDAY, MAY 21, 1919

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CARLE, N A *Report of Committee on Prime Movers*

STEAM POWER—The report discusses various phases of the problem of selecting turbines with proper regard to the size of the system as a whole and includes information as to the operating records of large-sized turbines, together with statements submitted by manufacturers reviewing progress during the past year.

The development of condensers, boilers, super-heaters, stokers, economizers and power station auxiliaries is covered in detail. The wider use of boiler and turbine room instruments is recommended as a means of checking operating conditions. Storage and handling of coal are discussed and several of the newest installations are described. Mention is made of the possibilities of the use of pulverized fuels and of lignites.

Further discussion of the advantages and disadvantages of higher steam pressures is included and brief reference is made to the proposed scheme of extracting by-products from raw fuel before firing under boilers.

WATER POWER—The report includes a general discussion of water-power developments during the past year and notes the tendency to go to fewer but larger units.

Improvements in details of general design are noted and the record of progress as submitted by manufacturers is included.

GAS POWER—The production of fuel oil from various fields in the United States is shown in tabulated form.

The development of Diesel engines has been mainly in the field of marine engineering, but improved design features are being incorporated in engines for land plants.

Reference is made to Bureau of Mines Bulletin No. 156 for exhaustive investigation and report on the Diesel engine. 7

MAGALHAES, F V *Report of Committee on Meters*

The report represents the work of the Committee since its appointment in January of this year. The matters handled by the Committee represent a continuation of previous work. such as Section X of the Meter Code, data on the performance of instrument transformers, meter lecture and one or two new subjects resulting from the war conditions, i. e., courses of instruction for training meter testers and data on meters on extended periodic schedules.

The practice of fusing potential transformers used with watt-hour meters and methods of measuring maximum demand on inductive circuits are also discussed briefly.

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W E Richards
F E Ricketts
D W Roper
L S Streng

FIRST TECHNICAL AND HYDRO-ELECTRIC SESSION

Tuesday, May 20, 1919

M. R. BUMP, Chairman.
R. J. McCLELLAND, Vice Chairman.

The Chairman called the meeting to order at 2:05 p.m.

THE CHAIRMAN: The first session of the Technical and Hydro-Electric Section will please come to order.

The first order of business is the Address of the Chairman of the Section, Mr. R. J. McClelland.

CONVENTION ADDRESS OF CHAIRMAN McCLELLAND

I am just returning from a several months' trip around the United States, and the first thing I find facing me here is an address. It must suffice to say that I have had no opportunity to prepare any address, and I doubt whether a formal written address would have added anything to the value of this meeting.

I will merely endeavor to express certain thoughts which have for some time been in my mind which seem appropriate to this occasion, although probably they will have no particular connection with our Technical Sessions. I feel that the work of the various Committees of the Technical Section has been in such able hands, and that there will be such opportunity for the Committee Chairmen and members to set forth their ideas, that there is no occasion for me to touch upon the subjects which will be brought out in this meeting, and in the other meetings which will follow.

This is a meeting primarily of engineers. I do not propose to go far into the much discussed question of the status of the engineer, but there is one point which I wish to emphasize, and that is the responsible position held by the engineer in this crucial period of commercial and industrial reorganization, when so many idle and bombastic theories are floating about, and there is so much talk of radical social and economic movements. I feel that the success of our Association and all associations of organized industries, as well as the success of the industries themselves, depends upon the intelligence and foresight of the individuals who take an active and leading part in them. Foremost among these should be the engineers. There is every reason why the engineer should be foremost. That he is not is due to his own limitations, limitations not inherent but remediable. Mr. E. W. Rice, Jr., several years ago gave an excellent exposition of this subject before, I believe, the American Institute of Electrical Engineers. He stated at that time, that in the United States Congress there were two men educated as engineers, both in the House. Recently in the West an engineer has been elected as Governor of a State, a man who had been State En-

gineer for a number of years. This is a hopeful sign. The small part taken by the engineer in the larger handling of things is without question due to the engineer himself. Among bankers and the executives of large undertakings, men who must analyze and pass upon engineering problems, you will find a tendency to question and disparage the recommendations of engineers. This comes about through the engineer being too intense, too much wrapped up in his own particular subject either to be interested in or to study those fundamental problems which control the decisions of executives and bankers.

After all we must realize, as I am sure many do, that it is the financial aspect which controls the operation of our commercial undertakings. If engineers as a body have not earned the complete confidence of executives, it is because these executives have found in their experience that the engineers have suggested and recommended operations and undertakings which were not commercially sound or which were not feasible at the particular time or under the particular circumstances involved. Had these engineers given thought and study to the financial conditions of the enterprise, they would probably not have made such recommendations or at least would not have made them in the way they did.

The executives and directing heads of large undertakings have practically all of them had their earlier experience along relatively specialized lines. Most of them have been lawyers or business men. Their assumption of executive responsibilities implies a broadening of judgment and capabilities. I feel strongly that if the engineer can demonstrate a similar ability to broaden his scope, he should be the best equipped man in the world to fill any executive position, because his whole training and experience for many years has taught him to analyze actual facts thoroughly, consistently and without prejudice. He has also learned by sad experience that, if his analyses and conclusions are not well founded, his mistakes will live forever after in concrete and steel masonry; something to which everyone may point and say "this is an engineer's mistake." The lawyers and those in other professions have not had this clear-cut check upon their work, with its incentive to care and caution.

Now whether, in this critical period, the country follows a

sound course or becomes involved with some of the unreasonable and irrational theories which are attracting so much attention, will depend largely upon the skill and soundness with which these new theories are analyzed by the country's educated and influential men. No group of men is in a better position to forecast the working out of industrial theories than the engineers. The ability to analyze facts, which is so specially developed in the engineer, affords the fundamental means of arriving at sane conclusions in such matters. There is little comparative experience available by which to reach conclusions, but sound analysis, properly presented and adequately spread before the public may be depended upon to eliminate vagaries and specious theories which seem to promise glittering immediate returns, but which have a ruinous future.

You men here present are from various portions of the country and are connected with the activities of various local organizations; the N.E.L.A., or the A.I.E.E., or various other technical societies. I feel that a determined effort should be made to introduce into the meetings of these societies a broader study of business and economic problems and of the effects of the present industrial and social situation. At a combined meeting of the N.E.L.A. and A.I.E.E, not long ago in Portland, Oregon, there was considerable discussion of the question of extension of the scope of their activities and of the necessity of considering problems beyond the immediate field of the engineer—for instance, matters of interest to accountants and commercial men. It was brought out at this meeting that earlier efforts to arouse mutual interest between these fields had been wholly unsuccessful, because each branch, and especially the engineers, would not give time and attention to anything except their own detailed problems. The existence of such a situation is a great mistake. It should be wholly feasible to put discussion of public utility problems on a plane broad enough to interest all of those engaged upon them, and this without detriment to specialized technical studies. The opportunity and necessity rest particularly with the engineer.

The N.E.L.A. at the present time is facing certain fundamental problems, problems as to the form of organization and method of conducting operations best adapted to yielding the

greatest advantages to its membership, to the electrical utilities of the country, and to the electrical industry as a whole. The electric light and power industry is now and will continue to be one of the most important in the United States. As such it should have an association which on the one hand should make possible the maximum benefit in the way of mutual assistance and interchange of ideas and experience, and which on the other hand should command respect from outside sources, and should be in a position to protect the common interests of its members.

It is a difficult and complicated problem, of course, to determine or to recommend the character of new steps which should be taken in the organization of our Association. It is probable, however, that during the next year certain radical changes will be made. There has been in recent years considerable criticism as to the effectiveness of the operations of our organization. On the one hand it has been said that we do not have sufficiently strong central organization to protect our common public and semi-public interests. On the other hand it has been pointed out that the Association, in view of its huge size and the wide geographical distribution of the industry, has outgrown its present centralized form, and that its operations are cumbersome and ineffective. This is especially true as to meetings and conventions. There are obvious difficulties in the way of Pacific Coast and Middle West men coming here to the Atlantic Coast, particularly when they come from relatively small organizations in which their absence constitutes a serious interference with ordinary operations and where the question of expense is a serious one. In our industry, revenue is being more and more closely regulated and limited, while expenses are tending in the opposite direction, so that executives are prone to cut off every expense which seems unnecessary and for which an immediate return may not be evident. (Applause.)

CHAIRMAN BUMP: I am sure we have all been interested in Mr. McClelland's talk. The vice-presidents of this Association are similar to the vice-presidents of the United States, "purely honorary." I will therefore now turn the Chair over to Mr. McClelland.

Chairman McClelland takes the Chair.

THE CHAIRMAN: The next order of business will be the appointing of the Nominating Committee to make nominations for the officers of the Section for the coming year. There are to be elected a Chairman, two Vice-Chairmen and one additional Executive Committee member. The remainder of the Executive Committee is elected for a two year term, and the incoming Chairman appoints the chairmen of the various committees, who automatically become members of the Executive Committee.

I will appoint to the Nominating Committee Mr. Thomas Sproule, Mr. Peter Junkersfeld, and Mr. R. F. Carbutt.

The afternoon is to be devoted to the consideration of the Report of the Committee on Prime Movers. As this is undoubtedly one of the most important reports which we have to consider, it has been decided to devote one entire session to the consideration of it. Heretofore, there has been considerable discontent and criticism on the ground that we have not had sufficient time for free discussion. Today we hope to give everyone who has something definite and concrete to say, time in which to say it.

I will ask Mr. N. A. Carle, Chairman of the Prime Movers Committee, to come to the platform and present his report.

REPORT OF COMMITTEE ON PRIME MOVERS

REVIEW OF COMMITTEE'S ACTIVITIES

Prior to 1904 the trend of development in prime movers had been followed by member companies through the presentation of papers and the general discussion of the subject at annual conventions.

By that time, however, expansion and development had become so rapid that it became necessary to centralize this work by assigning it specifically to a committee made up of leading men in the central station industry.

Accordingly, in 1904 the Committee for the Investigation of the Steam Turbine submitted its report to the Association. This report was the work of the Chairman, Mr. W. C. L. Eglin, assisted by Messrs. Fred Sargent and A. C. Dunham.

The report covered the subject under several headings, starting with a brief history of the art, and including manufacturers' descriptions of various types of machines, experience of users, efficiency tests and general conclusions to be drawn from the record of operating experience.

The investigation was continued along the same general lines and a second report was presented in 1905 by a Committee consisting of Messrs. W. C. L. Eglin, Chairman; A. C. Dunham, I. E. Moultrop, G. W. Cato and J. D. Andrew.

In 1906 the same Committee submitted a final report on the steam turbine, and requested that the Committee be discharged as it had carried the investigation to a point where it could be discontinued for the time at least.

No committee reported on prime movers in 1907, but the following year the subject of gas engines was taken up and its study continued until 1910. The original Committee on Gas Engines had W. C. L. Eglin as chairman and J. B. Klumpp and I. E. Moultrop as members. The subsequent chairmen of this Committee were J. B. Klumpp in 1909 and I. E. Moultrop in 1910.

In 1911 the present Committee came into being. In the list of committees published in the *Proceedings* of the Association

Manuscript of this report was received April fourteenth.

this Committee was called the "Committee on Prime Motive Powers." The report however was submitted under the heading of "Report of the Prime Movers Committee" and was called for as such by the President. This Committee was made up of the following members: I. E. Moultrop, Chairman; W. L. Abbott, C. J. Davidson, John Hunter, J. B. Klumpp, J. B. Sparrow, W. N. Ryerson.

The work of this Committee embodied the consideration of statements regarding turbine developments by the Allis-Chalmers Company, the General Electric Company and the Westinghouse Machine Company, as well as balancing of vertical turbines, elimination of condensate in steam supplied to low pressure turbines, condenser tube troubles, control of circulating water passes in surface condensers, cross connection of suctions of rotative dry vacuum pumps, wet vacuum pumps, cylinder oil for auxiliaries using superheated steam, step bearing oil, feed water heating in steam turbine stations, cleaning of air used for ventilating turbo-generators, larger sized boiler units, stokers, smoke prevention and the use of economizers.

There were five appendices to this report as follows:

A. Gas Producers, Gas and Oil Engines. By J. B. Klumpp.

B. Water Power Apparatus. By W. N. Ryerson.

C. Statements from Condenser Tube Manufacturers.

D. Condenser Lists Showing Comparative Results Between Three Pass and Single Pass Surface Condensers.

E. Description of a Purification System for the Ventilation of Turbo-Generators.

In 1912 I. E. Moultrop was again appointed Chairman and the Committee included in its report statements on water power turbines, governors and relief valves, stand pipes, penstocks, storage reservoirs and the measurement of water. The use of the auxiliary steam driven plant in connection with water power stations was discussed.

Under the subject of steam power the following topics were commented upon: purchase of coal on an ash basis, boilers of

large size, mechanical stokers, steam flow meters, feed water regulators, pitting of feed water piping, fatigue of cast iron used in connection with superheated steam, surface combustion boilers, high efficiency self-contained steam units, developments of the steam turbine during year by (a) Westinghouse Machine Company; (b) General Electric Company; condenser performance and economical vacuum, life of condenser tubes, moisture in the exhaust steam of engines and turbines, improvement in reduction gears.

A broad survey of oil and gas engine apparatus included consideration of oil available for power purposes, oil specifications for engine fuel, oil engines, results for oil engine plants, remarks on oil engine operators' experiences, oil producers, improvement in gas engine design, developments in the coal producer, the Humphrey gas pump, natural gas, utilization of gas or oil engine waste heat and gas turbines. The alcohol engine was also mentioned.

With I. E. Moultrop continuing as chairman in 1913, the Committee submitted its report in two parts, namely, Water Power, in the Hydro-Electric Session, and Steam Power in the Technical Session.

Statements from the General Electric Company and the Westinghouse Machine Company regarding the developments of steam turbines were included, and the subjects taken up in connection with steam engineering were turbines for station auxiliary purposes, the Ferranti high superheated steam turbine, low pressure steam turbines, high efficiency self-contained steam units, condenser design, new methods and devices, flow meters and forced draft, feed water heaters and feed water heating, deterioration of steel stacks, trouble with turbine blades, air supply for boiler houses in cold weather, balanced draft, feed water regulators, accuracy and value of CO_2 apparatus, meters for measuring feed water, fuel oil and its combustion, the Riley stoker and velocities in steam piping. Under the heading of Gas Power the topics discussed were oil engines and statistics regarding the general oil supply, gas turbine, the illuminating gas engine and the general high pressure transmission and distribution of power gas. The appendices attached to this part of the report were:

E. Oil Fuel and Its Combustion. By Arthur D. Pratt.

F-1. Specifications for Internal Combustion Engine Fuels. By Irving C. Allen.

F-2. European Specifications. (From "Engineering," March 22, 1912.)

F-3. Specification of Tar Oil Suitable for Diesel Engines. (From the German Tar Production Trust at Essen-Ruhr.)

G. Gas Power Situation in Europe. (Extracts from report by H. J. K. Freyn, Cons. Eng. Allis-Chalmers Co.)

H. Partial Digest of Recent Engineering Publications Bearing upon the Subject of Prime Movers or Accessory Apparatus.

In the water power section of the report the following subjects were discussed: vertical versus horizontal units, runner wear and material, testing of water wheels, stop and relief valves, stand pipes and surge tanks, penstocks and pipe lines, notable water power installations.

The appendices attached to this part of the report were as follows:

A. The Kingsbury Thrust Bearing. By W. W. Smith, Lieut. U. S. Navy. (Extract from *Journal of American Society of Naval Engineering,* Vol. XXIV, No. 4, Nov., 1912.)

B-1. Water Wheel Runners and Runner Material. By Allis-Chalmers Company.

B-2. In Regard to Water Wheel Runners and Runner Material. (Letter from I. P. Morris Co.)

B-3. Water Wheel Runners and Runner Material. (Letter from Viele, Blackwell & Buck.)

B-4. In Regard to Water Wheel Runners and Runner Material. (Letter from Wellman-Seaver-Morgan Co.)

B-5. In Regard to Water Wheel Runners and Run-

ner Material. (Letter from the Ontario Power Co. of Niagara Falls.)

C. Efficiency Tests of Water Wheels after Installation. By Prof. C. M. Allen, Worcester Polytechnic Institute.

D. Johnson Type Penstock Valve. (Letter from the Wellman-Seaver-Morgan Co.)

The subjects considered in the 1914 report, submitted by the Committee with I. E. Moultrop as chairman, are divided into three main headings: steam power, water power and gas power. The topics taken up are given under these headings.

Steam Power

Cost of steam stand-by service supplementing water power, plant and transmission line, forced draft for peak service, emission of smoke and cinders from chimneys, pulverized coal burning, under-water storage of coal, fire brick, steam flow meters, surface combustion, notes on condensers, boiler tubes, foreign practice and tendency, the Ferranti turbine, letters from manufacturers—De Laval Steam Turbine Company, Westinghouse Machine Company, Southwark Foundry and Machine Company, General Electric Company, Henry R. Worthington.

Water Power

Methods of measurement of water in operation, instruments and devices used, general principles governing the selection of water wheels, use of center bearing between runners in horizontal double runner center discharge wheel settings, and alignment of wheels of this type, recent results with Kingsbury thrust bearing, water wheel testing flume.

Gas Power

Heavy type oil engines, fuel oil situation, generation and distribution of producer gas, Humphrey Gas Power Pump.

Appendices

A. Progress of Cleaning of Flue Gas in Steam Power Plants. By C. B. Grady.

B. The Determination of Flow of Rivers in Relation to Hydraulic Developments.

C. Method used by S. D. Warren & Company of Comparing Theoretical and Actual Plant Output.

D. Kingsbury Thrust Bearings.

E. Geographical Distribution of Oil Engines in the U. S.

F. Prices of Crude Oil in U. S.

G. Petroleum Production in 1913.

H. So. Staffordshire, England, Mond Gas Plant and High Pressure Producer Gas Distribution.

The 1915 report was divided into three main parts, namely, steam power, water power and gas power and was submitted by the Committee with I. E. Moultrop as chairman.

The steam power section includes the discussion of the Riley, Westinghouse and Taylor stoker development, coal dust burning, fusibility of ash, economizers, air leakage in boiler and economizer settings, instruments for checking boiler performance, statements by the General Electric and Westinghouse Companies on steam turbines, statements by the Westinghouse Machine Company, Wheeler Condenser and Engineering Company, and H. R. Worthington on condensers, improvements in the older type of condensers, new method for determining surface condenser leakage, air cleaning for turbo-generators and the possible effect of carbonate of soda in boilers.

The water power section commented on progress in water wheel design in the following papers:

1. Practice in High Head Hydraulic Plants by J. P. Jollyman.
2. Methods of Water Measurement by Prof. C. M. Allen.
3. An Analysis of Water Wheel Governor Effort by E. D. Searing.

This section also considered open versus closed type of oil

pressure governor systems, considerations applying to open as compared with closed systems and the Government testing flume at Niagara.

The gas power section discusses the following subjects: Oil production, Diesel oil engine industry, Humphrey pump progress, gas engines, gas producer development. Gas producers in the United States and the European trend are described in a letter by R. H. Fernald. The appendices to this report include:

A. Bibliography of books, pamphlets and papers referring to subjects discussed in report.

B. Paper by Prof. C. M. Allen, previously referred to under water power.

The papers by J. P. Jollyman and E. D. Searing were also attached. There was a sub-committee report on Water Power Development on the Pacific Coast, P. M. Downing, chairman.

The 1916 report was divided into three main parts: steam power, water power and gas power, and the scope of the discussion was detailed under these headings. I. E. Moultrop acted as chairman.

Steam Power

Statements by General Electric Company and Westinghouse Electric and Manufacturing Company, on steam turbines; statements by Westinghouse Electric and Manufacturing Company, Wheeler Condenser and Engineering Company, and H. R. Worthington on condensers, condenser tubes, sand blast cleaning of condenser tubes, boiler rating, higher steam pressure in turbine stations; a paper—"The New Era of Higher Steam Pressures," by Robert Cramer; fuel oil under boilers; a paper—"Fusion Temperature of Ash and Its Effect on Commercial Use of Coal," by John P. Sparrow; coal sampling methods, description of ash fusion methods, Riley, Taylor and Westinghouse stokers, fire brick linings of boiler furnaces, external cleaning of boilers, instruments for checking boiler and turbine performance, welded pipe joints for high pressure and superheated steam service and uniflow engines.

Water Power

Progress in water wheel design and installation, develop-

ment of water powers from an economic standpoint under present conditions, reliability of hydraulic prime movers, troubles with hydraulic prime movers, water measurement by use of salt solution, Government testing flume.

Gas Power

General statement on the status of gas engines and producers, Diesel engines, résumé of the fuel oil situation, construction and operating data on Diesel engines. The appendices include:

A. Hydro-electric Development on the Pacific Coast. By John Harisberger.

B. Reliability of Hydraulic Prime Movers and Causes of Shut Downs on the Pacific Coast. P. M. Downing.

C. Influence of Ice on Hydro-Electric Developments. R. M. Wilson.

D. Bibliography.

The 1917 report was considerably more brief than previous reports and papers, and small mention was made of gas power development. J. M. Graves was the Chairman of this Committee.

Steam Power

Statements by the Westinghouse Electric and Manufacturing Company, Allis-Chalmers Manufacturing Company, and the General Electric Company on steam turbines, statements by the Westinghouse Electric and Manufacturing Company, Wheeler Condenser and Engineering Company, and H. R. Worthington on condensers, power house auxiliaries, stokers (Cox, Taylor, Westinghouse, Murphy and Riley) duplex stoker settings, extra large stoker retorts and maintenance of brick work were included.

A discussion of refractory materials embodied the consideration of abrasion test, slagging test, softening test, expansion or contraction, wall construction, heat insulation, and air proof coatings.

The following topics were also commented upon: coal handling apparatus, storage, weathering and spontaneous combustion of coal, the mercury boiler, higher steam pressures in turbine stations, higher boiler pressures, opinions of distinguished engineers on higher steam pressures, an insurance view of higher pressure, steam velocities in piping and fittings, economical pressure drop in steam lines, boiler room instruments, turbine room instruments, analyses of auxiliary power requirements using either steam driven or electric driven auxiliaries and boiler feed water treatment.

Gas Power

This portion of the report included a discussion of the Diesel engines and a résumé of the fuel oil situation.

Water Power

This portion of the report mentioned the subjects of progress, general tendencies in design, development in runner design, development in intake and draft tube design, corrosion and erosion of submerged parts and oil lubrication of thrust bearings, papers on "Brakes for Hydro-Electric Units," by W. F. Uhl; "Frazil Ice Handling Methods," by J. A. Walls; operation of small generating stations without an attendant, water wheel testing code as given in report of the Power Testing Committee of the A. S. M. E. of 1915 with resolution as to desirable changes, and a paper—"An Improved Water Level Gage for Remote Indication," by F. H. Howes.

In 1918 it was found impossible on account of the difficulties which beset the whole industry, to carry on the work of the Prime Movers Committee, and no report was submitted that year. However, the Chairman of the Technical Section, in the absence of Mr. J. M. Graves, the Prime Movers Chairman, read an abstract of the subjects investigated, with the idea that member companies which were interested might follow up the various subjects by correspondence. The subjects dealt in the main with operating problems and included material on the inspection, handling and storage of coal, and the operation and maintenance of the boiler plant.

TURBINES

Size of Units and System Capacities

The accompanying tabulation shows the total generating capacity of a number of large central station companies as of May 1st, 1919. It also shows the generating capacity in machines of 20,000 kv-a. and larger, as well as the relation which this capacity bears to the total generating capacity. In the third column is the capacity of the largest unit and its percentage of the total capacity. With cross compound machines having two and three prime movers and generators, the complete machine is considered as a unit.

While this list may be subject to revision in minor details, it gives an idea of the tendency of the times so far as the installation of large generating units is concerned.

It can readily be appreciated that the system which has a large fraction of its generating capacity tied up in one unit, is staking its reputation on the successful performance of that unit and for that reason the manufacturer must naturally feel a heavy responsibility.

TABLE I

CENTRAL STATION SYSTEM CAPACITIES AND LARGE UNIT INSTALLATIONS AS OF MAY 1, 1919

Company and Location	Generating Capacity Total Kv-a.	Capacity in 20,000 Kv-a. and Larger		Capacity of Largest Unit	
		Kv-a.	% of Total Kv-a.	Kv-a.	% of Total Kv-a.
Buffalo Gen. Elec. Co. Buffalo, N. Y.	105,555	105,555	100.	38,889	36.8
Con. Gas El. Lt.& Pr. Co. Baltimore, Md.	81,500	40,000	49.1	20,000	24.5
Boston Elev. Ry. Co. Boston, Mass.	122,500	35,000	28.5	35,000	28.5
Edison El. Illg. Co. Boston, Mass.	143,000	30,000	21.0	30,000	21.0
Alabama Power Co. Birmingham, Ala.	140,233	58,333	41.6	33,333	23.1
Edison Elec. Illg. Co. Brooklyn, N. Y.	121,500	52,000	42.8	30,000	24.7
Bklyn. Rap. Tr. Co. Brooklyn, N. Y.	139,850	51,100	36.6	30,000	21.5
Commonwealth Ed. Co. Chicago, Ill.	498,510	227,910	45.7	35,300	7.1
Cleveland El. Illg. Co. Cleveland, O.	208,000	150,000	72.1	31,250	15.0

Company and Location	Generating Capacity Total Kv-a.	Capacity in 20,000 Kv-a. and Larger Kv-a.	% of Total Kv-a.	Capacity of Largest Unit Kv-a.	% of Total Kv-a.
Union Gas & Elec. Co. Cincinnati, O..........	84,400	50,000	59.3	25,000	29.6
Northern Ohio Trac. Co. Cuyahoga Falls, O.....	67,000	44,444	66.3	22,222	33.2
Detroit Edison Co. Detroit, Mich.........	193,000	105,000	54.4	45,000	23.3
Pennsylvania R.R. Co. Long Isl. City, N. Y.	78,000	41,100	52.7	21,100	27.1
Twin City Rap. Tr. Co. Minneapolis, Minn....	65,000	20,000	30.8	20,000	30.8
Moline Rock Is. Mfg. Co. Moline, Ill...........	50,600	20,000	39.6	20,000	39.6
Interborough Rap.Tr.Co. New York City.......	389,000	256,000	65.8	70,000	18.0
New York Edison Co. New York City.......	286,000	111,000	38.8	30,000	10.5
*Public Serv. Elec. Co. Newark, N. J.........	265,100	105,000	39.6	35,000	13.2
United El. Lt. & Pwr. Co. New York City.......	124,900	65,900	52.8	25,900	20.7
Philadelphia Elec. Co. Philadelphia, Pa......	279,700	153,900	55.0	35,000	12.5
Narragansett El..Ltg. Co. Providence, R. I......	85,500	67,500	78.9	47,500	55.5
Duquesne Light Co. Pittsburgh, Pa........	168,000	47,200	28.1	47,200	28.1
N. Y. C. R. R. Co. Pt. Mor. & Yonk., N.Y.	60,000	20,000	33.3	20,000	33.3
Reading Tran. & Lt. Co. Reading, Pa..........	25,000	25,000	100.0	25,000	100.0
Un. El. Lt. & Pwr. Co. St. Louis, Mo........	83,000	25,000	30.1	25,000	30.1
United Electric Co. Springfield, Mass........	45,020	20,000	44.4	20,000	44.4
Toledo Ry. & Lt. Co. Toledo, O............	88,000	45,750	52.0	23,500	26.7
Worcester El. Lt. Co. Worcester, Mass......	43,000	20,000	46.5	20,000	46.5
Wheeling Electric Co. Windsor, W. Va.....	69,000	60,000	87.0	30,000	43.5

*Based on Northern Zone capacity.

Maximum Sizes of Turbo-Generators

The opinions expressed and summarized in previous reports still prevail in so far as the maximum size of turbo-generators is concerned. Due to conditions imposed by the war, all efforts toward development and production were limited to a large extent to such devices and apparatus as were required to meet the national emergency.

During the past two years, nevertheless, there has been a marked increase in the number of large units in operation, par-

ticularly the horizontal, single shaft type of approximately 30,000 kw. capacity. This condition has been brought about by the necessity for meeting the rapidly increasing density of load, particularly in our larger centers of power supply, and the recognized reliability of operation recorded for this size of unit.

A consideration of the practical limit in size of single shaft machines, so far as the questions of design enter into the problem, indicates that in general higher efficiencies at equal or less cost per kilowatt output can be obtained as the size of the unit is increased, particularly in capacities up to 30,000 kw.; and although one single unit of 45,000 kw. capacity is now in service, it cannot be assumed that the size of single shaft units can be increased indefinitely.

From a manufacturing standpoint, the limitation in size of a single shaft unit is a limitation arising partly from materials at present available for blades and revolving elements and also from several inherent constructional difficulties which must be cleared away before further increases are fully justified.

In addition, there is also involved the question of economic value of increased size of machines above 30,000 kw. If such factors as maximum efficiencies, cost per kw., and space requirements show a fairly uniform betterment as the size of the unit is increased, then neglecting the factors of design and operation, an increase in the capacity of the single unit will show a saving with increased system load demand.

It would appear, however, that with the present constructional problems with the prevailing frequencies and speeds and the recognized factors of safety, efficiency and cost, the size of systems today will hardly warrant units larger than 30,000 kw. capacity. In particular cases, and until increased reliability, as well as improvements in operating efficiencies, have been established, even larger systems will not justify the use of larger units.

Balanced against these machine characteristics must also be considered the system characteristics—size of load, load factor, available running time and minimum reserve capacity. As the proportion of single unit size to the system load is increased, there is obviously an added necessity for increased reliability, as well as for a higher grade of operating supervision.

The problem that must be considered, therefore, in increas-

ing the size of horizontal, single shaft units, is one relating both to the question of system capacity and of economic considerations of design and construction. During the entire period of the development of steam turbine generator units, central station companies, in order to increase their operating efficiencies, have in many cases purchased new designs before their reliability had been demonstrated. With the increasing proportion and importance of the individual unit as compared with the system capacity, it is of increasing importance in considering the future problems of operating these large units that progress be such as to insure more definitely that the demands of the central station companies for greater reliability of service can be met with an adequate degree of certainty.

Continuity of Service

The increasing size of prime movers and the increasing percentage which the individual turbo-generator unit bears to the total generating capacity of any system make the reliability of this type of machine a matter of much more importance from the operating standpoint than it was previously considered. While every one appreciates the reduction in overhead charges due to the low investment cost per unit installed for these large machines, the low operating cost due to their increased efficiency and the low attendant labor and maintenance costs, yet operating companies must not forget for an instant that continuity of service is the bed rock of any central station company's reputation and that the truly successful public service company must give the community it serves the best and most reliable service possible.

With the increase in the size of the system and the recent increase in size of single units, an individual prime mover and generator often comprises 25 per cent or more of the total generating capacity of many large companies, and the importance of these large units, as well as the necessity for their continuous operation have increased proportionately. It is therefore becoming increasingly necessary on account of overhead charges to attempt to safeguard this capacity, and the reliable operation of the unit is absolutely essential to the satisfactory operation of the system.

While it is most commendable for any public service com-

pany to purchase that machine which will give, not only the lowest investment cost per kilowatt, but also the lowest operating cost per kilowatt-hour, there is a definite relation between the capacity of the individual unit and the capacity of the system beyond which it is neither safe nor wise to go. When the failure of a unit jeopardizes the service, the company's reputation is at stake, and the loss in prestige built up by years of faithful service may be more costly than the comparatively small saving in operating costs.

Just how far it is safe to go in the installation of large generating units, each company must of course decide for itself, but since units of over 20,000 kw. capacity are a rather recent development and since the service factor or ratio of hours available to total hours for some of these units is 90 per cent or less, as compared with 97 to 99 per cent for some of the older units, the importance of giving this matter careful consideration is evident.

On the other hand, it must not be forgotten that certain of these large machines have records of continuous performance and output which surpass anything previously considered possible. For example, one of the 25,000 kw. units operated at 67 per cent load factor during a 51-day run without shutdown; another machine of the same capacity has completed two 77-day runs, at 67 per cent load factor in the first instance and 70 per cent in the second, while one of the 35,000 kw. units operated at 65 per cent load factor for a 70-day run without shutdown.

Records such as these encourage central station companies to depend upon a single unit for over 25 per cent of their generating capacity.

Troubles with Large Units

During the past few years a very marked development has been experienced in both the increased number and size of steam turbo-generating units in plants of the larger operating companies. This exceptionally rapid advance is largely due to two factors; first, the necessities of large operating companies to meet satisfactorily the service demands placed upon them, and second, the important changes in design and construction, resulting in lowered cost and improved operation, that have made

practicable the manufacture and operation of larger sized single units.

The experience of the operators with these latest types of horizontal single units of 20,000 kw. capacity and above, covers a period of practically three years. Therefore, any statement concerning these units at this time, which deals with their relative successes as compared with the smaller and earlier types, can hardly be regarded as altogether conclusive. Another element also to be recognized is that during this comparatively short period of time, not only the manufacture but also the operation have been carried on under most adverse conditions as affecting both labor and materials. Nevertheless, a number of serious accidents, which have occurred only recently throughout the country, cannot be lightly regarded, particularly at this period of increasingly high standards of service and operating economies.

In analyzing the causes of trouble as indicated by the operating records of the class of units of 20,000 kw. and over, there are several features of design that appear to be the most frequent sources of trouble. Labyrinth packings and thrust bearings have probably contributed to the major part of large turbine operating difficulties. While these troubles in themselves have caused a considerable loss in operating time, they have also been responsible in a considerable number of instances for the development of far more serious troubles. Among these may be mentoned excessive vibration of parts, breaking of buckets, and dangerous rubbing of stationary and moving elements, which, in extreme cases, have resulted in permanent deflection of shafts.

The most serious situation that has developed in the type and sizes of units under consideration, however, has been the number of quite recent turbine wheel failures. In several instances these accidents have resulted in the complete wrecking of the units concerned. Such accidents, which are without parallel in the history of steam turbine development, can hardly be considered as bearing directly on the question of performance of large sized units, but rather as a factor to be considered in the improvement of design and construction of a specific type of unit.

The situation is now a critical one, and, while any definite statement at this time would be premature, the Committee wishes

to indicate the necessity for early action both in safeguarding against further possible failures of machines now in operation, and in reaching definite solutions of those problems which involve important features of design and construction.

In general, however, the records of operating performances of these larger sized units, while too incomplete for definite conclusions, do indicate that there is every reason to expect as high a standard of performance for the recent types of large capacity single shaft units as had been obtained in the operation of machines of earlier design and smaller capacities. It is hardly over-stating the case, however, to say that the records for reliability of operation of the larger units, during the past two years, have not been up to this standard.

While some of the difficulties may, without doubt, be directly concerned with operation, the greater percentage of trouble has been the direct result of shortcomings in details of design, materials or construction. On smaller sized units, however, similar details of construction have proved to be much more reliable in their operation. It would seem that not only is the same degree of reliability of operation essential, but that a greater degree of reliability becomes more imperative with increasing sizes of machines and higher standards of service demanded by those industries dependent upon electric power supply.

Standby Operation of Turbines

The subject of "standby" or "floating" operation of a turbine, *i.e.*, running it at or near zero load, is of special interest to companies having steam plants connected to transmission systems normally fed by hydro-electric power. There are two main cases: the first, or standby service proper, in which the turbine is kept running with steam at the throttle, so as to pick up load promptly in case of hydro-electric plant or line failure; and the second, or voltage regulating service, in which the turbine unit is motored from the generator end, using the latter as a synchronous condenser and employing only such steam as is necessary to prevent heating in the steam end. The first of these cases is the more important, as the standard turbogenerator is not especially fitted for synchronous condenser service, on account of field limitations, and because the losses are much greater than in a condenser designed for the purpose. Actual experience has

been had with one or both classes of floating service on hydro-electric power transmission systems at various points on the Pacific Coast, in Colorado, at St. Louis, and in several parts of the East.

According to information received, it is necessary with practically all types of turbines of any considerable size to maintain some steam passing through the turbine, to prevent injurious heating of the rotor and stator parts due to churning of the air. With boilers hot and ready to furnish considerable quantities of steam at short notice, the supplying of a few thousand pounds an hour does not call for heavy additional expenditure. It is even found advantageous in some cases to pass enough steam through the turbine to carry a few hundred kilowatts load, as this tends to give stability to the operation. The governor is adjusted so that load will be picked up by the turbine as the frequency of the system drops, from trouble or other cause. Difficulties are sometimes encountered due to a sensitive turbine governor, the steam machine tending to take up system fluctuations rather than leaving this duty to the hydro-electric plants.

The chief problem in normal standby operation is to determine how steam use can be kept at a minimum, still maintaining the turbine ready to pick up load without delay. In any case the turbine valves should be adjusted to take the smallest amount of steam consistent with safety to the internal parts and with proper regulation.

For standby operation it is desirable that the exciter be direct driven by the turbine. It is necessary to maintain a vacuum on the turbine, and to keep the condenser auxiliaries in operation, and these would preferably be motor driven if the steam turbine is of sufficient size to maintain frequency and voltage with trouble on the transmission line or in the hydro-electric plants running in parallel; if the turbine cannot be expected under these conditions to hold up speed and voltage, the important auxiliaries should be steam driven or should have a combination electric and steam drive, with the electric used normally but with the steam drive arranged to pick them up at the time of serious trouble on the system.

One of the most important features in keeping down expense in standby operation is the manner of handling the boilers, a full treatment of which is outside the scope of this discussion. With

coal fuel, either an underfeed stoker, or a forced draft chain grate stoker, or perhaps powdered fuel, may be chosen for this banking and quick steaming work; in many instances oil or other liquid or gas fuel can be used to advantage. It is difficult, however, to use oil successfully, in a normally coal fired furnace, to give quick steaming in emergency. The speed of the stoker or the supply of fuel oil can, if desired, be made automatically responsive to an increase in load. There are various schemes of keeping the boilers up to a reasonable pressure, such, for instance, as keeping one boiler fired actively and using live steam therefrom in all others. It is very desirable to have a large storage of hot water in the heaters and in auxiliary tanks to assist in maintaining maximum evaporation during the first few minutes of active turbine operation.

It appears that the operation of steam turbines at no load in parallel with hydro-electric systems is tending to become less frequent, not only on account of the necessity for rigid economy, but because hydro-electric plants and transmission lines are becoming more and more reliable. It is in general only for the most important load and with inferior hydro-electric system operation that this standby operation is advisable. When the floating service becomes necessary, great care and skill should be exercised in keeping steam plant costs at a minimum; this is especially necessary with steam plants not specially designed for economy during standby operation, but even in stations planned specifically for such service a considerable saving can usually be made by careful study of operating methods.

MANUFACTURERS' STATEMENTS

Your Committee is in receipt of statements from the following manufacturers covering developments during the past year:

Allis-Chalmers Manufacturing Company

Since the last meeting of the National Electric Light Association, manufacturers have had little opportunity for special development work on steam turbines. The requirements of the Government for equipment for use in connection with the prosecution of the war, on account of the urgency of this demand, of necessity restricted the choice of the apparatus to the standard lines of equipment, and development work has had to be postponed until the return of normal times.

The most prominent and significant feature in the course of steam turbine progress during the last twelve months is the return to favor of the medium size unit of approximately 10,000 to 12,000 kw. capacity, from which it would appear that operating engineers are beginning to realize the disadvantage of installing units of unduly large capacity, preferring rather to install medium size units with slightly less thermal efficiency but with greater reliability, and the fact that the shutting down of any one piece of apparatus on account of trouble or for periodic inspection and overhauling causes much less interruption in the service, is no doubt a reason for the popularity of this size of unit.

During the last year we placed in operation a number of units of approximately the sizes given above, and in each case the machines were started up without a hitch and have maintained an enviable operating record to date. Six machines have been placed in service and seven others are nearing completion.

In all cases the generators were manufactured in our own shops, and in four of the installations already in operation we also manufactured the condensers and condenser auxiliaries, which in these cases places the responsibility for the complete generating equipment up to one manufacturer, an undoubted advantage from the purchaser's point of view.

On account of their excellent operating record, a brief description of these machines may be of interest to the members of the Association.

To obtain maximum economy the turbines are of the single flow reaction type, embodying all the improvements gained by our engineers in fifteen years' experience in the manufacture of steam turbines. The blading is of our well-known substantial construction, mounted in an exceptionally rugged spindle, and the special care taken during all processes of manufacture to insure an accurate balance, not only of the spindle and spindle rings but also of the segments of blading, without doubt contributes very largely to the smooth operation of the completed rotor.

The turbine spindle and generator rotor are each carried in their own bearings, suitably connected through a flexible coupling efficiently lubricated by a patented method of lubrication. The four bearing method of support permits the ready inspection of either turbine or generator without disturbing the other element.

The turbine cylinder is split along the horizontal joint, thereby permitting ready access to the interior of the machine for periodic inspection, and the ends of the cylinder where the spindle passes through are effectively sealed against any inleakage of air by means of our well-known water sealed glands. These glands, not being subject to wear except to that occasioned by the churning action of the water, insure effective sealing after long continuous operation, and contribute to the maintenance of the best possible vacuum obtainable by the condensing equipment.

The bearings of both generator and turbine are of the ball and

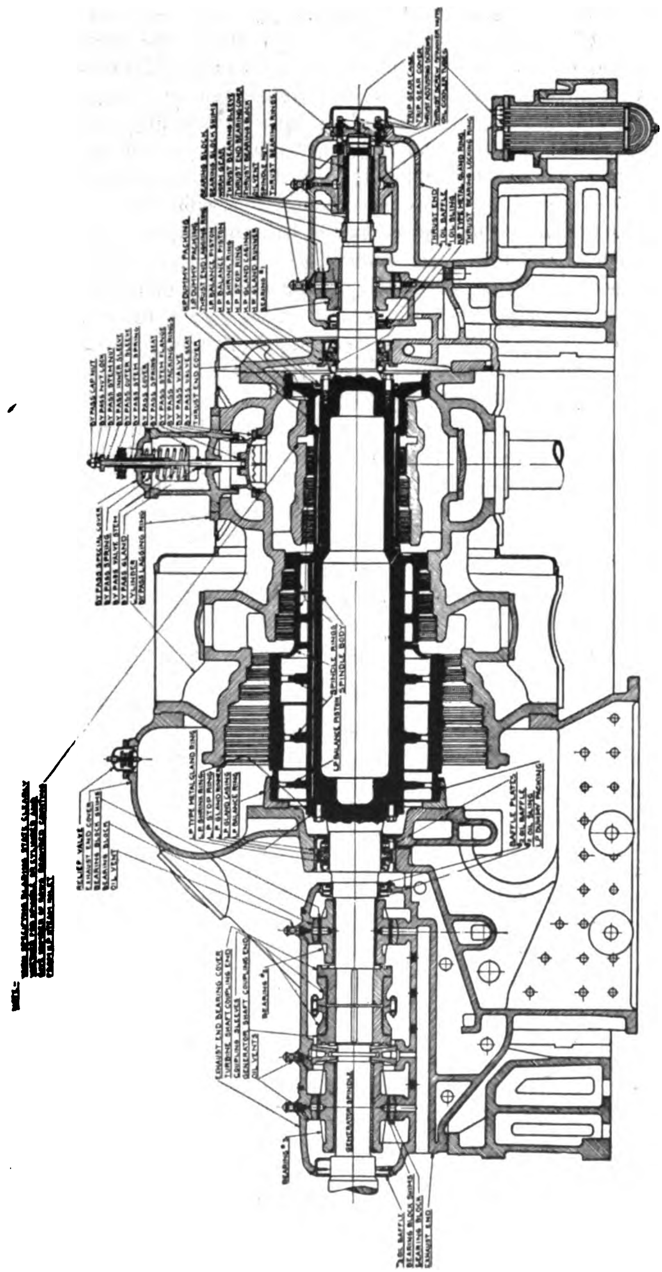

Fig. 1—Cross Section of Allis-Chalmers Turbine

socket type lined with babbitt, and are lubricated by means of forced lubrication. Above each bearing a visibile leak-off is provided, which enables the operator to observe at all times that oil under pressure is maintained at each bearing, and also permits any air which might accumulate at the bearing to escape without endangering operation. This particular feature is patented and is the exclusive right of our company.

The turbine and generator are mounted on a continuous bedplate of very rugged construction, and the throttle valve and steam chest, including the steam strainer and inlet valve with its oil relay mechanism, are bolted rigidly to this bed plate, a flexible steel connection being provided between the steam chest and the cylinder. This construction prevents the possibility of any strains being imposed upon the turbine cylinder, due to steam piping, etc., and permits the free expansion of the turbine cylinder under variations in steam temperature.

In addition to the usual pedestal supports at each end of the cylinder, a substantial foot is provided around the exhaust nozzle which is supported on the bed plate. With this added stiffness in construction the expansion joint usually provided in the exhaust pipe can be eliminated, if the condenser is suitably supported on springs to carry the weight of this part of the equipment.

As is customary, a by-pass valve is provided directly operated by the governor to admit steam to a lower stage of the turbine in the event of an exceptionally high load, or to maintain operatioh in case of an extreme drop in the steam pressure.

A self-contained forced lubricating system, including a suitable oil cooler, is provided for bearing and governor lubrication, and for the purpose of supplying oil for the relay system for operating the valves. In addition an oil filter of large capacity is furnished to withdraw continuously a portion of the oil for the purpose of removing water and other impurities, automatically returning the cleansed oil to the system.

For use when starting up and stopping, and also in case of emergency, a steam turbine driven submerged centrifugal oil pump is provided and a suitable pressure regulator is installed to start up this auxiliary oil pump automatically in case of an undue drop in pressure in the system from any cause whatever.

In general, the turbine is of rugged construction, built for continuous service and is of pleasing appearance, and, judging from the reports furnished by customers who are operating these units, they have given unqualified satisfaction.

A cross section of our standard machine is shown in Fig. 1.

General Electric Company

Since our last statement two years ago in reference to turbines, war conditions, have, of course, made the undertaking of new commercial development on a large scale very difficult. It was necessary, nevertheless, to carry through the new designs which we had already started

and to do a great deal of development work to meet the requirements of the Navy and Emergency Fleet Corporation.

At a time when we were hard pressed for skilled labor of all kinds, it was extremely difficult to give the time and attention necessary to the development of new designs. The engineering and manufacturing organizations could not be expanded quickly enough, by the addition of thoroughly trained men, to meet fully the enormous demand which suddenly came upon us. We, like all other manufacturers, suffered severely on account of the loss of skilled men who went in the service, over 8000 employees leaving us on this account. These men had to be replaced by less skilled men and in addition a greatly increased force recruited from all sources.

We also experienced great difficulty in securing the quantity and quality of materials required for the manufacture of turbines. The producers of all lines of materials and accessories were surfeited with business, were required to carry on production under the same disadvantages that we suffered from, and in endeavoring to meet the demands for maximum production undoubtedly encountered most serious obstacles in the way of maintaining quality equivalent to pre-war standards.

The severe handicaps under which we were working were necessarily reflected to some extent in the turbines manufactured during this period of stress, and a number of machines have been subject to trouble of one kind or another. Cases of trouble have not, by any means, been confined to turbines of new types but have occurred in recently built turbines of the older types.

Actual experience was required to show that our inspection system, which had previously proved to be amply protective, was not under the new conditions sufficiently thorough or comprehensive, and it has been necessary to elaborate it. This has been done, and with the return to more nearly normal conditions the severe handicaps under which we have been working during the last two years are being removed. We feel greatly encouraged by the results already attained and have the utmost confidence that from this time on the production and operation of Curtis steam turbines will be on the same satisfactory basis that existed in former times. No radical changes in existing designs of turbines are contemplated. The general features of design of a 7500 kw. and a 45,000 kw. machine are shown in Fig. 2 and Fig. 3.

A very large number of turbines and gears have been furnished to the Emergency Fleet Corporation for propelling cargo boats and to the U. S. Navy for destroyers. In addition, turbo-generators have been supplied and are on order for the electric propulsion of large warships for the Navy. For the latter purpose turbo-generators of individual capacity up to 35,000 kw. are on order.

The Company has built and will continue to build direct current turbo-generators, also turbo-generators for special application, including steam extraction, low and mixed pressure units, and turbines for mechanical drive.

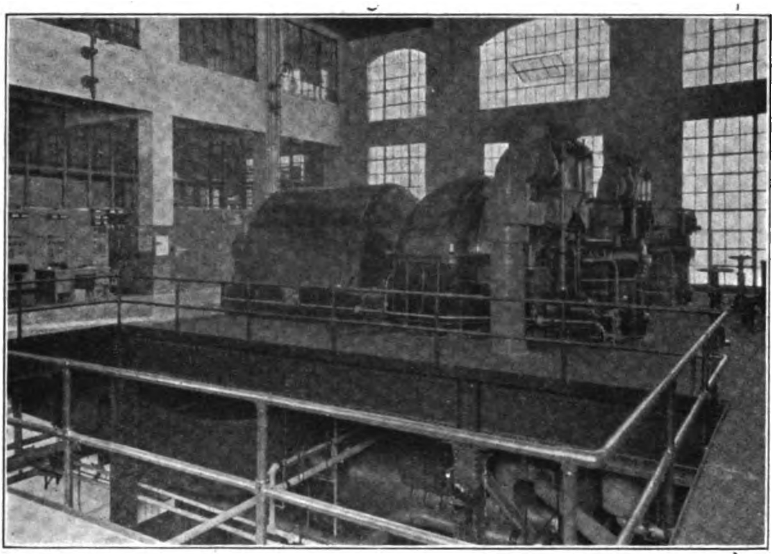

Fig. 2—General Electric 7,500 Kw. Unit

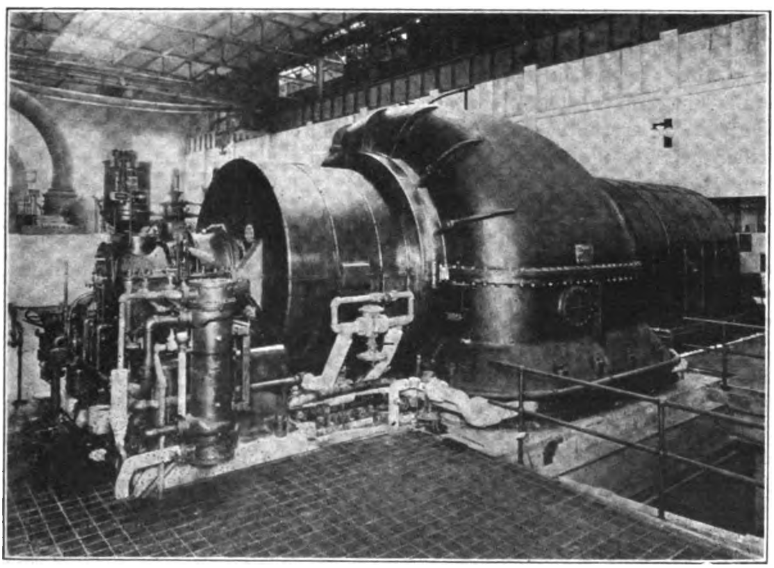

Fig. 3—General Electric 45,000 Kw. Unit

Kerr Turbine Company

Kerr turbines are of two principal types—the older or multi-pressure impulse type, and the newer or velocity stage turbine. They are built for high pressure, condensing, noncondensing low or mixed pressure service. A large number of turbines for marine propulsion and many of the extraction or bleeder type have also been built.

Recent developments on our turbines consist chiefly of the perfecting of mechanical details on the multi-pressure stage machine, and complete design of the velocity stage machine for small horse powers.

Our turbines are designed primarily to be absolutely reliable, safe and satisfactory in operation, as this, in the opinion of engineers, constitutes the main requisites of a piece of machinery. All rotating parts are designed to give the maximum strength, and are carefully machined, ground and balanced. Clearances between rotating and stationary parts are large. Bearing temperatures are kept low.

Even though steam economy is considered of secondary importance, particularly for small machines, our turbines embody certain features of design, as will be outlined later, which permit them to show a performance for the majority of conditions unexcelled by any other turbine builder.

The casings in both of the above-described types of turbines are made up of steam and exhaust ends which are provided with supports for bolting to bed plate and between which are the circular steel or iron diaphragms containing the nozzles for the pressure stage turbine, and intermediate holders with reversing chambers for the velocity stage type. The diaphragm castings are arched at the center and are centered with each other and with the two end castings by turned and bored tongue-and-groove joints packed with fibrous packing laid in graphite and oil. The sections are bolted together by continuous stay bolts passing through drilled holes in the flange of one end of the casting and tapped into the flange of the other. The diaphragms are split and when bolted together with exhaust and steam ends, the upper halves form a cover which may be lifted, exposing the entire rotor for inspection or repairs. For smaller size turbines the end castings are each bored to receive the main bearing cases. A section through one of the smaller types of turbines, as shown in Fig. 4, brings out the general features of design.

It is generally known and appreciated that the fact that diaphragms can be added or removed from certain frames of turbines without any change other than lengthening or shortening the turbine shaft, is of the greatest advantage from the thermodynamic standpoint. The thermodynamic efficiency of a turbine of any type, excluding windage friction, is a function of the ratio between blade and steam velocities. By adding stages for exceptional conditions, such as low rotating speeds, high steam pressures and good vacuum, and removing stages for conditions in the opposite extreme, namely high rotating speeds, low steam pressures and high exhaust pressures, it is possible to adjust the number of stages

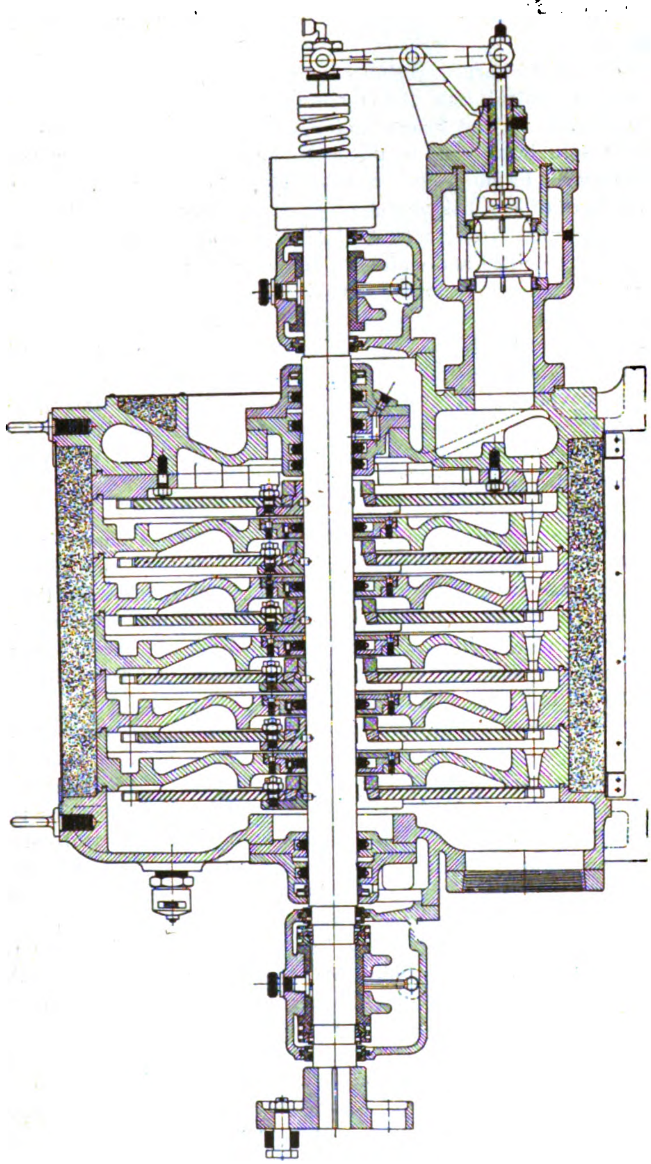

FIG. 4—SECTION THROUGH KERR ECONOMY TURBINE

so as to get the best possible efficiency for each condition. The sectional construction lends itself extremely well to complex conditions of operation. So, for instance, condensing turbines are built to develop full load; non-condensing and bleeder turbines can be made to bleed the total

amount of steam at bleeder pressure; in other words, operating non-condensing, etc.

On rotors of the larger size machines the bucket wheels are forged integral with a central hub and forced by hydraulic pressure onto a tapered steel shaft. In the smaller units each bucket wheel is bolted onto a three-piece split hub, fitted to the shaft and kept from lengthwise or rotating movement by pin keys. A split mitred key is forced by a lock-nut into the bore of the disk and against a turned taper on the hub. The wheels are machined from sheet steel or steel forgings, depending upon their size, and are drilled and slotted to receive the shanks of the buckets. The buckets are made of a nickel steel particularly well adapted to withstand erosion. Buckets undergo a heat-treatment to get the maximum strength and are restruck by a special method to get the best possible finish, which will decrease the steam friction and increase the efficiency. Buckets are provided with a shank and bulb at the inner end and are inserted sideways into the rim of the wheel and securely rivetted into place. This type of blading is undoubtedly the safest of any used in modern steam turbine practice.

Steam is admitted through a double beat balance valve, the stem of which is connected on the smaller turbines through one single lever to the governor. On larger machines instead of the direct acting governor, a so-called oil relay governor controls the movement of the valve through a small oil pilot which operates the piston of the main steam valve. Turbines are provided with an overspeed governor on the main shaft as an additional precaution in case, through some accident, the main governor should fail to function.

Leakage of steam along the shaft at the steam and exhaust ends and between stages is prevented by floating carbon packing rings, held in place by spiral springs and stops. The packing at the steam end consists of a number of these rings with two leakage connections taken from selected points between them and piped to the low pressure stages. On condensing turbines one of these leakage pipes is connected to the exhaust end packing so as to form a steam seal and prevent air from being drawn through this packing to the condenser.

The main bearings are of the self-aligning split, babbitt lined type, and on the larger size are provided with oil under a pressure of about six pounds, the oil being supplied by a reservoir in the bed plate and the required pressure being obtained from a gear pump attached to the lower end of the governor spindle. Before being used the oil is forced through a nest of water-cooled brass tubes located in the bedplate, and after having passed through the bearings is returned to the reservoir. On the large units a small auxiliary turbine-driven centrifugal oil pump, bolted to the reservoir and with impeller submerged in the oil, automatically serves the bearings with oil while the turbine is being started or stopped. On smaller size turbines ring oil lubrication is employed.

The general design of Kerr turbines in both large and small sizes is illustrated in Figs. 5 and 6.

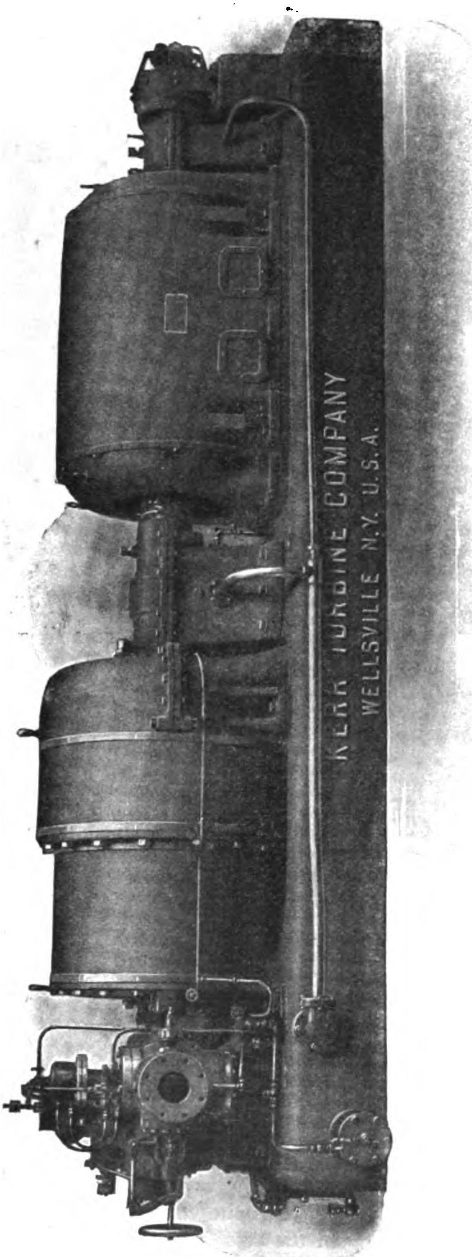

Fig. 5—Kerr Turbine Driving 1,000 Kw. Generator

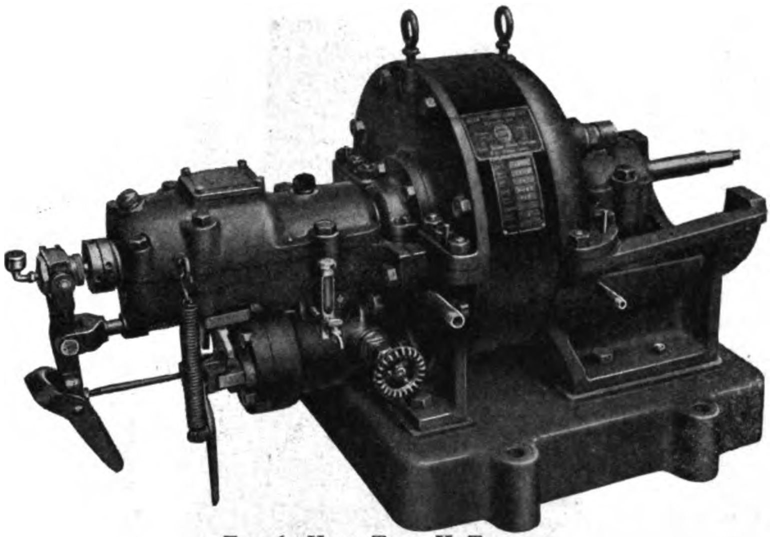

FIG. 6—KERR TYPE K TURBINE

Westinghouse Electric and Manufacturing Company

The accompanying figures give information regarding our tandem and cross compound turbines:

Type	*Weight*	*Length*	*Width*	*Height*	*Rating*
Tandem.......	1,200,000	72′ 9″	20′ 9″	20′ 9½″	35,300 kv-a.
Cross Compd..	1,360,000	47′ 8″	42′ 2″	18′ 9″	47,200 kv-a.

The above data cover the tandem machine we built for the Commonwealth Edison Company and the cross compound we built for the Duquesne Light Company and the Narragansett Electric Lighting Company. In both cases they are 60 cycle units, the Commonwealth running at 1200 RPM, while the cross compound runs at 1800 RPM for the high pressure and 1200 RPM for the low pressure. You will see that the weight per kilowatt for the tandem is somewhat greater than the cross compound. However, this weight per kilowatt would be very close for both cases if we could compare exact sizes.

The cost per kilowatt of the two sizes may be assumed to be practically identical. The steam end of the tandem machine is somewhat more expensive, while the two generators on the cross compound will exceed the cost of the single generator about enough to equalize. The difference in efficiency between the two types is within 2 per cent.

As to a general comparison of the two types from a manufacturing standpoint, we can build either type quite comfortably, although it is perhaps a little easier to turn out the cross compound machine. It is more of a job to assemble the tandem machine complete on the testing founda-

tion than it is to test the high and low pressure elements of the cross compound separately. The stresses in both types are quite low, the materials employed are of ordinary, readily obtained quality, and the testing and inspection is all of a character well within the usual standards of good shop practice.

Whatever there is to be said about the two types bears more particularly upon the operation side, and on this question opinions will differ. There are some engineers who seem to prefer the single shaft unit, as they feel that the single generator best fits the operating conditions. The tandem machine has the merit of dividing the cylinder structure into two parts, which removes the problem of design that comes with an excessively large single cylinder structure with its possibilities of instability. It also confines the high temperatures to a small steel cylinder, a point of particular importance as we approach the question of higher temperatures of steam. It is true that a mishap in either cylinder would be likely to disable the whole machine.

Our own view has rather favored the use of two separate elements in these larger sizes, and, as you know, we have gone to three elements in the 60,000 kw. size. We think that the cross compound offers the maximum assurance of operating reliability. We do not see anything in the operation of a 40,000 kw. cross compound that presents any new problems over operating two 20,000 kw. single units. The three 30,000 kw. machines at the 74th Street Interborough plant in New York have had a four years' operating record, so there has been a good deal of actual experience with them. If actual operation means anything, they have proved out. From a design standpoint nothing could be much simpler. The cross compound machine should perhaps be looked upon from an operating viewpoint as one unit, but there is the point that if anything happens to the high pressure side, the low pressure can be operated at about half the unit capacity, and so your eggs are not quite all in one basket. The operating record of the tandem machines at Chicago has been so good, however, that they have certainly justified the type, but it still remains true that a mishap could put the entire tandem unit out of service, which with the cross compound machine still enables you to use half of its capacity.

Summing up a comparison of the two types, the choice between them seems to be more a matter of taste or opinion than one of defined judgment. The record of large turbines up to date has proved one thing, that the single cylinder design has found its limit of reliability and efficiency at 25,000 to 30,000 kw.; that above 30,000 kw. we must go to the multi-cylinder type in order to have the mechanical design sufficiently reliable to justify these larger sizes. And it seems also true that we must go to these larger sizes for our bigger stations in order to get the operating cost where it belongs. If it be said that equally high efficiency could be secured in smaller machines, such as 20,000 kw., the answer is that the cost per kilowatt to achieve that result would be prohibitive.

In addition to the record of progress on large machines, your Committee has received the following statements from manufacturers regarding small turbines for driving auxiliary equipment:

General Electric Company

About three years ago we developed a line of turbines particularly for mechanical drive applications and known as the type "L." Since that time, we have sold over 90,000 horse power for this class of service alone, the number of machines being between 800 and 900, and the operating record of the machines has been exceptionally good.

The line of turbines includes machines from 10 to 500 horse power at speeds up to 3600 rev. per min. Any steam pressure and superheat may be used up to the highest in commercial use in large stations.

These turbines meet two conditions: First, that individual machines are designed to suit each customer's particular operating conditions; and second, that the foregoing can be accomplished with a machine made up from parts manufactured on a quantity basis.

Both of the above ideas are carried out, and the type "L" machine combines a machine designed to meet any given set of conditions, and, at the same time, one which is built on a quantity production basis.

Each machine is made up of standard parts, which are, in the main, as follows: Nozzle plates, shaft and wheels, high pressure head, wheel casings, exhaust head, operating governor, governor valve, emergency valve.

Nozzle plates are made up in quantity, but the nozzles are not drilled until an order is received. The shop is equipped with engineering data to make nozzles suitable for use with wheels having buckets of different heights, and for each height there are reamers available giving nine expansion ratios. A machine, for example, can be equipped with from one to fifty small nozzles or from one to twenty-eight large nozzles, and each one of these nozzles may be furnished with any one of nine expansion ratios. The ratio of areas possible between one small nozzle and the maximum number of large nozzles is 1 to 90, and, as may be figured from the above data, the progress from the smallest to the largest area can be made in 702 separate steps. It will easily be seen from the above that the statement that the nozzle is designed specifically for the customer's conditions is correct for all practical purposes.

The wheels are made up with different bucket heights, and each bucket height is made with two sets of bucket angles, known as the high speed and low speed combination. Any of these may be supplied with clockwise or counter-clockwise rotation. Or, in other words, there are a number of different standard bucket wheels carried in production. Any of these may be supplied with alloy or steel buckets, depending on temperature conditions, and any wheel or combination of wheels may be assembled, depending on whether a one, two or three stage tur-

bine is required. Three shafts are provided to take care of machines having different numbers of stages.

A high pressure head with a short nozzle arc is used for small horse powers, high steam pressures, or for such conditions as require a small number of nozzles. This head is furnished in steel or iron, depending on temperature conditions. A long arc head is used when more nozzles are required than can be assembled with the short arc head, or in all cases where a hand valve is required. This head is also furnished in iron or steel, depending on conditions.

An exhaust head with 8-inch diameter exhaust is used on all machines having a steam flow up to the capacity of the 8-inch opening. A 14-inch head is used for steam flows beyond the capacity of the 8-inch head. The 14-inch head may be furnished either right or left hand or looking downward.

A partially dis-assembled Type L turbine is illustrated in Fig. 7 which brings out the noteworthy features of design.

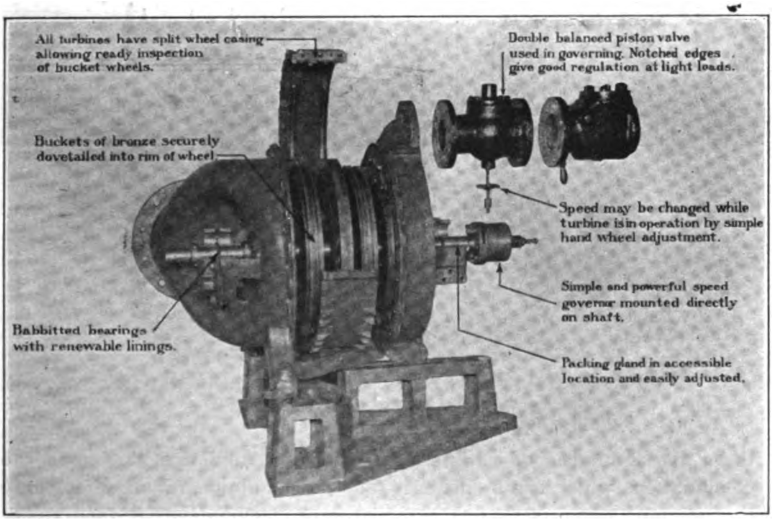

Fig. 7—General Electric L Turbine Partially Dis-assembled

The diaphragms are furnished in either steel or iron, depending on steam temperature and pressure conditions. On receipt of customer's order, the diaphragms are drilled with the proper number and kind of nozzles.

The operating governor is furnished for speeds from 1200 rev. per min. to 3600 rev. per min. by using various combinations of standard weights and springs, and when assembled for a given normal speed may be adjusted while the machine is running for a considerable range of speed from normal.

The operating governor and valve are assembled with the governor lever as well as with a hand wheel, by which the speed of the machine may be regulated while the turbine is in operation. To accomplish this speed change, the regulation of the governor is made broad, *i.e.*, there is a wide variation between the speed at which the governor weights commence to move and the speed at which they have reached their maximum travel. The movement of the weights is several times that necessary to move the governor valve from entirely open to entirely closed. Consequently, by moving the hand wheel, the operating range of the governor may be adjusted at any position between the minimum and maximum speeds determined by the movement of the weights.

From the foregoing description, it will be evident, although the type "L" machine is in general made up from a very few parts, that

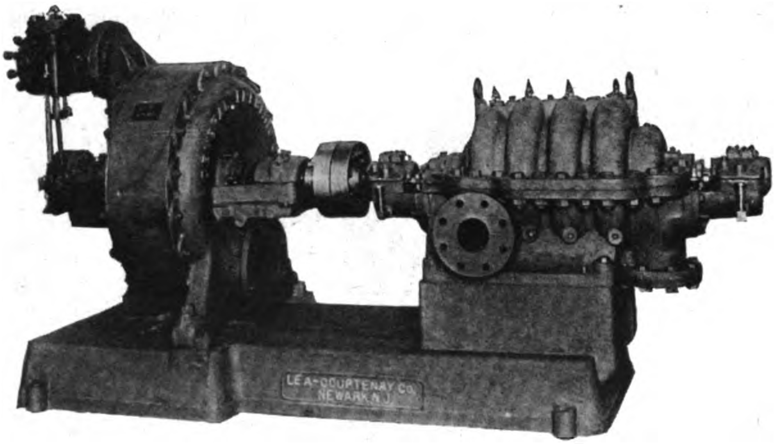

FIG. 8—GENERAL ELECTRIC TYPE L TURBINE DRIVING LEA-COURTENAY PUMP

there are a number of variations to each part and that the number of combinations which can be made is practically infinite; or, in other words, that it is no exaggeration to say that each machine is designed exactly for the conditions for which it is sold.

All machines, whether built with one, two or three stages, have the wheel casing split, so that the top half of the casing may be lifted without dis-assembling the machine and the bucket wheels and nozzles readily inspected. The turbines may be furnished with a speed control governor, or with a safety stop only, for cases where the turbine is used to drive a boiler feed pump, and the speed is controlled by a water pressure regulator. Both governors may be supplied if required, and the steam inlet may be placed vertically, thus making a machine well suited for use in cramped positions where space is at a premium.

In order to produce type "L" turbines in accordance with the plan

laid out, it has been necessary to equip a new shop for the manufacture of these units, where all operations have been standardized and where a large number of special machine tools have been installed to permit rapid and economical manufacture.

The type "L" turbine has been sold largely for use in driving pumps of various kinds, but is well adapted for driving any of the auxiliary apparatus in a central station. The design has been thoroughly standardized and tested by several years of operation under all sorts of operating conditions, and the type "L" turbines have been found to be uniformly satisfactory. Fig. 8 and Fig. 9 show the application of this type of turbine for pump drive.

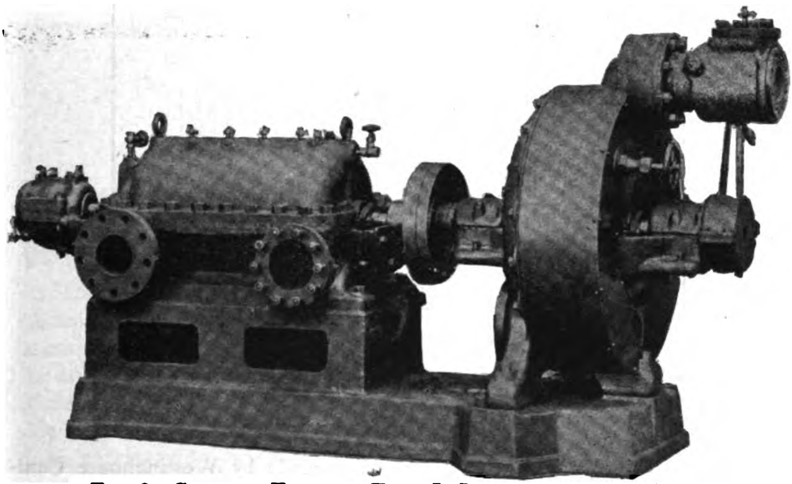

FIG. 9—GENERAL ELECTRIC TYPE L TURBINE DRIVING PUMP

The Steam Motors Company

The advantages of the steam turbine auxiliary over the reciprocating type, with the pressures and temperatures encountered in modern central station practice, have been sufficiently well established, so that no comments on this phase of the subject are necessary at this time.

The relative merits of the electrical drive vs. the turbine drive will be dealt with later.

The impulse principle is used exclusively for all small machines, as the reaction or Parsons type is commercially impracticable below say 500 horse power.

Four distinct types of machines are now extensively used, the principles of which are shown diagramically in Fig. 10.

A. The helical flow type made by the Terry Steam Turbine Company, B. F. Sturtevant Company and Whitton & Company.

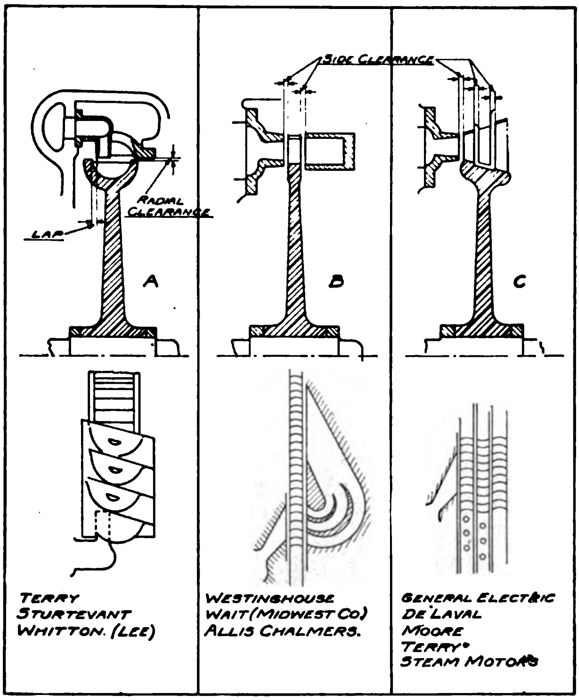

FIG. 10—DESIGN FEATURES OF VARIOUS CLASSES OF TURBINES

B. The single wheel reentry type made by Westinghouse Company, Allis-Chalmers Company and Mid-West Engine Company.

C. Multi-wheel velocity stage type made by General Electric Company, DeLaval Steam Turbine Company, Moore Steam Turbine Company, Terry Steam Turbine Company, Alberger Company and Steam Motors Company.

In addition to the above, there is Group D which consists of multi-stage machines made up of several pressure stages, incorporating one or more of the principles enumerated above, or using the straight Rateau principle having only one velocity stage per pressure stage.

The machines in this group are manufactured by the General Electric Company, Kerr Steam Turbine Company and Moore Steam Turbine Company.

As in larger machines, considerable development has taken place during the last few years in the designing of small turbines to meet the requirements called for with changing operating conditions.

Based on the difficulties experienced with the designing of the

earlier machines, this development has been directed principally along the following lines:

1. To increase the general reliability by more rugged designs to insure permanent alignment; misalignment being responsible for a great majority of the troubles experienced with long machines having a multiplicity of bearings.
2. A general appreciation of the fact that the so-called flexible coupling is *not* flexible at high speed, and a general tendency to eliminate its use in modern designs.
3. The design of the supporting members of the casing to eliminate excessive raising and lowering of the center line of the shaft with large ranges in temperature.
4. Refinements in the design of glands to pack effectively against large ranges of back pressure without the use of lubricants.
5. The design of casings so that cast steel can be used in such places as are subjected to high temperatures without the necessity of making all the casing proper of steel and the subsequent risk of excessive scrappage.
6. Increasing the efficiency due to the decreasing demand for exhaust steam for feed water heating with the use of economizers.

There can be no hard and fast law laid down as to the standard of efficiency or water rate that must be reached in the small auxiliary turbine. In many cases a low efficiency machine is not only permissible but desirable. In other cases, where the requirements of exhaust steam are limited, efficiency is of considerable importance, but in no case must it be considered of primary importance if its reliability is impaired by complications necessary to obtain the desired economy; each proposition must, therefore, be considered in the light of the particular requirements of the station.

The difference in steam consumption with these machines cannot be capitalized in anywhere near the same degree as in the main unit, if an efficient utilization of the exhaust steam, either in the feed water heater or main low pressure turbine, is possible.

By referring to the diagram Fig. 11 it will be seen that a very large range in actual water rate has a really very small effect on the heat balance of the station.

Beginning with the boiler feed pump, it is generally accepted that this should be steam driven rather than electrically driven to insure continued operation in the event of electrical disturbances in the main circuits. Also the location of such pumps often makes the presence of any electrical appliances very undesirable.

Furthermore, to insure the maximum of reliability, the simplest possible type of prime mover is desirable at this point even at a sacrifice of efficiency, if it is at all possible to use the exhaust steam.

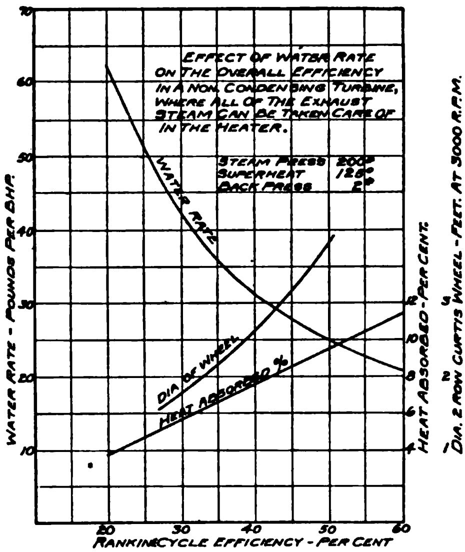

FIG. 11—OPERATING CHARACTERISTICS OF SMALL TURBINES

If it is not efficient to use turbine driven auxiliaries throughout the station, a dividing line can be drawn where it is advisable to switch over to electrically driven units; special attention being paid to the location of said units and the degree of intelligence of the various attendants.

As this dividing line where the limit is reached for utilizing all the exhaust steam is variable, depending upon the load in the station, a most desirable connecting link is the duplex driven pump or exciter, consisting of one pump or generator, driven either by steam or by an electric motor, with switchboard control enabling one or the other of the prime movers to be used as the requirements of the heater may dictate.

Reverting again to the efficiency of the turbine itself and how far reliability may be sacrificed to obtain a better economy, this again, in a large measure, must be determined by the location of the machine and the grade of operators employed to look after it.

For circulating pumps, where large quantities of water are required at low heads, the geared turbine unit finds its ideal field, and on account of the possible presence of leaks and moisture is far preferable to an electric drive.

For other service, pumps, etc., the small power required and the little saving that can be accomplished in the overall heat efficiency, between a single stage machine and one of the more efficient multi-stage or geared type, should be an argument in favor of the single stage type.

The fact must not be lost sight of that taking a single stage machine

with a certain known efficiency, this efficiency can be increased only by increasing the diameter of the wheel or by increasing the number of stages, in both instances resulting in a marked increase in first cost and greater complications due to increased duty on the bearings, increased number of glands to keep tight, etc.

Referring again to Fig. 11, the average efficiency in a well designed unit will be found to fall between the limits of 35 and 45 per cent. The difference in water rate between these two machines is 36—27.5=8.5 lb., or at 45 per cent efficiency the water rate is bettered 23.6 per cent, but the total difference in heat absorbed by the turbine is only 2 per cent.

On the same curve is plotted the approximate diameter of a single stage 2-row Curtis wheel to give the required efficiency. At 35 per cent the wheel would be 2.2 ft. in diameter and at 45 per cent 3.2 ft. It has been found in practice that the cost of wheels and complete machine, and the weight of runner and complete machine, vary very closely as the square of the diameter, so that in a single stage machine the 45 per cent machine would cost twice that designed for 35 per cent.

To get the same increase in economy, by staging, using the 2.2 ft. diameter as a basis, we would need 4 or 5 stages, assuming 1 Curtis and 2 or 3 Rateau stages or 2 Curtis stages, resulting in the same ratio of cost, etc., as by increasing the diameter.

Also in both cases, it will be noted that the duty on the bearings is double.

One marked advantage of a single stage machine in large central stations is that any one frame can be jetted to cover a large range of horse powers. It is easier to line up than a long machine, and therefore given a number of different drives using the same frame in any one station, a spare or idle machine can be transferred from one duty to another, by the simple replacement of the nozzle block to suit the particular requirements. In other words, the utility of this type of machine is the same as that of an electric motor.

To summarize the points brought out above:

1. The design of the whole machine should be considered from a standpoint of reliability in preference to water rate efficiency in all cases.
2. Where exhaust steam requirements are limited, a multi-stage or geared machine should be considered from the viewpoint of overall economy and not water rate only, as brought out in Fig. 11. The point is to determine whether with a big reduction in water rate, the net overall saving warrants the additional complications, or whether it would be better to have fewer lower efficiency machines and at the point of "maximum exhaust steam" to switch over to electrical drive.
3. The location of the machines and the grade of attendants

employed should be considered seriously in deciding the type of machine to adopt. For instance, a highly efficient automatic nozzle control geared generator on the main engine room floor, coming under the direct supervision of the chief engineer and his skilled assistants, would be eminently satisfactory. On the other hand, the same machine, placed, say, in the basement, under unskilled helpers, would be inviting trouble.

4. At the dividing line between steam and electrically driven units, the duplex pump or generator set should be considered as forming an admirable compensating device for maintaining a proper heat balance.

CONDENSERS

The last two years have taxed the condenser builders in the same difficult way as other manufacturing establishments. The necessities of war have restrained development to a certain extent. Condenser builders seem to have had about all they could do to meet the vast requirements thrust upon them by the great national manufacturing program and the rapid expansion of marine work.

During this period, however, there has been developed the steam air ejector, which has come into a very prominent place in marine work, and is rapidly coming to the front in its application to power plants. Its unqualified success at sea has shown that it is an apparatus that will soon occupy a very prominent place in future condenser installations. We, therefore, believe it should be brought to the attention of those concerned with condenser equipment for power houses.

The following firms are manufacturing air ejectors applicable to condenser service, that is, to take the place of the present reciprocating or hydraulic air pumps:

Westinghouse Electric and Manufacturing Company,
C. H. Wheeler Manufacturing Company,
Alberger Pump and Condenser Company,
Wheeler Condenser and Engineering Company,
Elliott Company.
Croll-Reynolds Company.

Ejectors as made by the various manufacturers are usually

built in two stages, each stage partially compressing the air by ejector action. In one design of this apparatus, the second stage handles both steam and air from the first stage. In another, there is a condenser between the two stages which condenses the steam delivered from the first stage so that the second stage has to compress air only. Better efficiencies and steam consumptions are obtained with this latter type; but as the steam consumption of ejector apparatus is generally low in comparison with the total auxiliary steam, manufacturers of the type not using the intermediate condenser claim that the extra complication is unwarranted. This is probably a fact where the station has a proper heat balance, inasmuch as the ejector without the intermediary condenser returns practically all its heat to the heater. This latter characteristic is a thing worth mentioning. As pointed out by the ejector manufacturers, while the steam consumption of an ejector may be slightly higher than that of a hydraulic air pump of the same capacity, its overall efficiency is greater. The hydraulic air pump takes its water from the intake tunnel and discharges back into it, losing the heat equivalent of the mechanical work done. It also loses some heat due to the discharge of steam and heated air from the condenser. The steam ejector can discharge into a surge tank, and thus recover practically all the heat that it uses. A sketch of the Westinghouse-Le Blanc type is shown in Fig. 12.

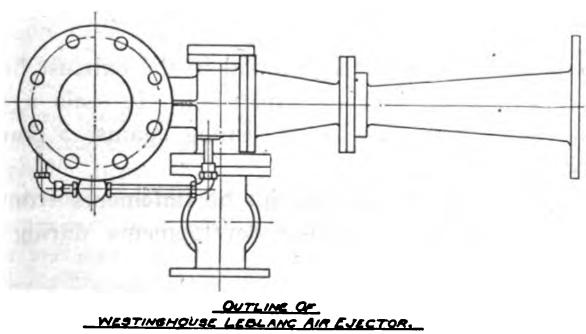

FIG. 12—OUTLINE OF WESTINGHOUSE LE BLANC AIR EJECTOR

Some caution, however, must be used in the installation of these ejectors. The difficulty is that the exhaust from the ejector contains all the air that has been pumped out of the con-

denser. It is not safe to discharge the steam and air from these ejectors into the present type of heaters. There should be installed a large surge tank into which the make-up and the discharge from the air ejectors should be carried. The tank should have a free atmospheric vent for the discharge of the air, allowing the water from the tank to overflow into the heaters.

During the last two years a number of the larger condensers installed on General Electric turbines in power stations have been put on spring supports without expansion joints. This method seems to be very satisfactory.

The Westinghouse Company recommends hanging the condenser from the turbine foundation, which method is also satisfactory, as it accomplishes practically the same results as the spring. In one case, where the condenser was located 50 feet below the turbine and there was an unusual amount of expansion in the exhaust piping, the expansion joint was of the mercury type. This expansion joint, which is illustrated in Fig. 13,

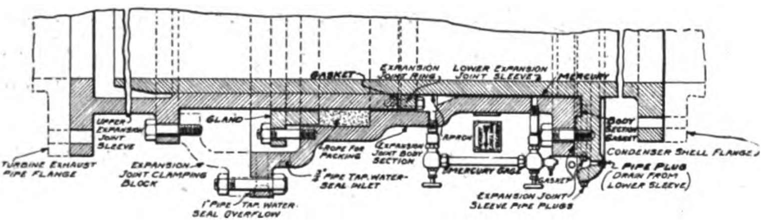

FIG. 13—MERCURY EXPANSION JOINT

is nothing more than a mercury seal in the exhaust line, and it allows absolute freedom of expansion. It seals against any vacuum and is even capable of sealing against 5 pounds back pressure.

Your Committee is in receipt of statements from the following manufacturers covering developments during the past year:

Alberger Pump and Condenser Company

The Alberger Air Occluder is of the ejector type of air removal apparatus, using steam as the impelling medium. It is illustrated in all its desirable static simplicity in Fig. 14, and as attached to a surface condenser in Fig. 15.

The Occluder consists of two stages arranged in series with an inter-

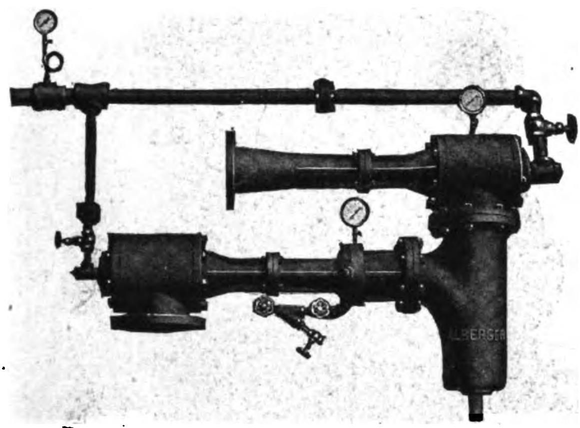

FIG. 14—ALBERGER AIR OCCLUDER

cooler of either the surface or jet type placed between them. The first stage is connected to that part of the equipment from which the air and non-condensible vapors are to be removed, and is so constructed that the entering steam entrains the air and non-condensible vapors and compresses them to the pressure existing in the intercooler.

The mixture of steam and air and non-condensible vapors is then discharged into the intercooler, which by condensing the steam and cooling the air and noncondensible vapors reduces the volume to be handled by the second stage. This, in turn, reduces the amount of steam required for operating the second stage, permitting the handling of high ratios of compression, and, as a result, the total quantity of steam required by the Air Occluder is relatively small. Without the intercooler the same quantity of air and non-condensible vapors would be handled, but a much larger quantity of steam would be necessary for operating the second stage.

It can be seen readily from the above that by condensing the steam used in the first stage, the air handling capacity for a given amount of steam is greatly increased.

The second stage withdraws the gases from the intercooler and discharges them against atmospheric pressure or against a back pressure not to exceed one pound above atmospheric, permitting the use of the exhaust steam for heating purposes.

The quantity of intercooler water required is small and can be utilized for boiler feed make-up. When used in connection with a surface condenser, provision must be made in the design of the condensate pump to handle the additional amount of cooling water necessary for the operating of a jet intercooler, although this item may be neglected if a surface intercooler is used. The temperature of the intercooler water should be no higher than that used for condensing purposes.

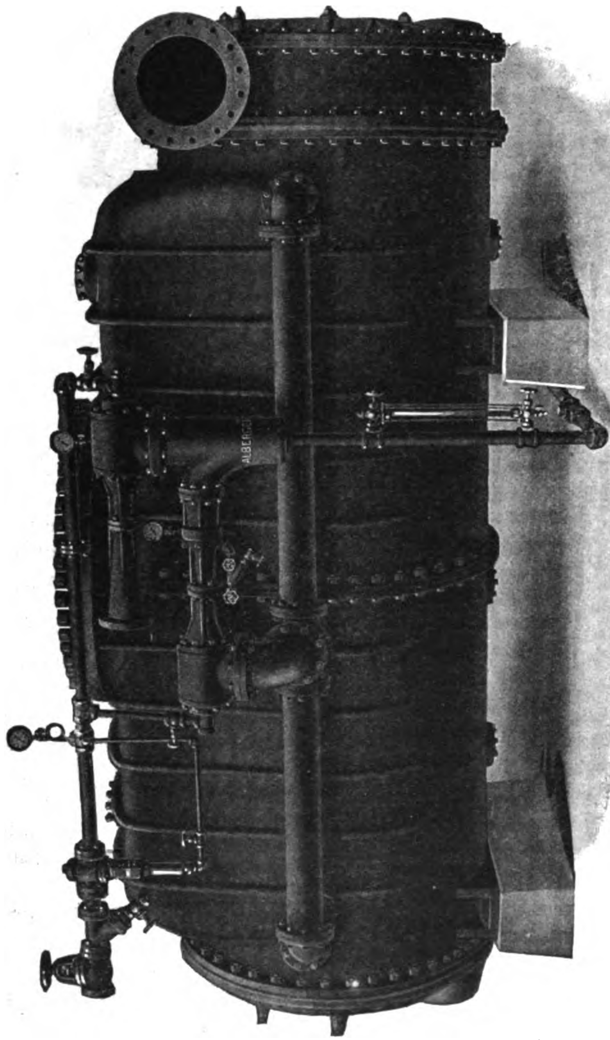

FIG. 15—SURFACE CONDENSER EQUIPPED WITH ALBERGER OCCLUDER

Croll-Reynolds Company

The Evactor Air Pump is of the steam jet type, using an intercooler between stages. It differs from all others in having two second-stage nozzles, and with this arrangement we are able to furnish an air pump which has three different capacities instead of one. The illustration of the Evactor in Fig. 16 brings out the general features of design.

The three air handling capacities are obtained by the following arrangement of nozzles:

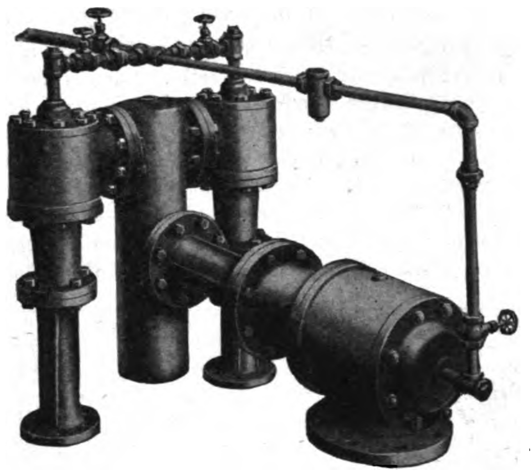

FIG. 16—CROLL-REYNOLDS EVACTOR

First capacity—First-stage and one of the second-stage nozzles in operation.

Second capacity—First-stage and the other second-stage nozzles in operation.

Third capacity—First-stage and both of the second-stage nozzles in operation.

You can readily see the advantage of this arrangement, as it is a well-known fact that the amount of air to be removed from the condensing equipment cannot be predetermined. Therefore, if there were a large air leakage, the large capacity would be used, and if there were a comparatively small leakage, the small capacity would be used.

The steam nozzles of the Evactor are of Monel metal, the exhaust nozzles of bronze and all other parts except the nozzle strainers are of cast iron. Another advantage of our air pump is in having the strainers directly fitted over the steam nozzles instead of having them in the lines leading to the nozzles. It has been found by experience that a strainer placed in the steam lines leading to the air pump is not satisfactory, as the scale from the piping between the strainer and the steam nozzles often causes trouble.

We give you herewith an idea of the economy of the Evactor:

CAPACITY

Cu. ft. free air per min. at 2" abs.	Steam Cons. in lbs. per hr. 150 lbs. I. S. P.
6.0	430 lbs
9.5	570 lbs
16.5	850 lbs

Wheeler Condenser and Engineering Company

Referring to the cross-sectional view, Fig. 17, steam for both nozzles enters through the valve shown at the right. Part of this steam passes upward through the curved steam line to the primary nozzle, as plainly indicated. The high velocity attained by the steam in passing through the first nozzle creates suction in accordance with the principles of the injector, and ejects air from the main condenser through the opening marked "air inlet." This air and the steam from the jet itself are then forced into the inter-condenser, where the steam condenses.

The secondary-stage nozzle now does its work. The same steam

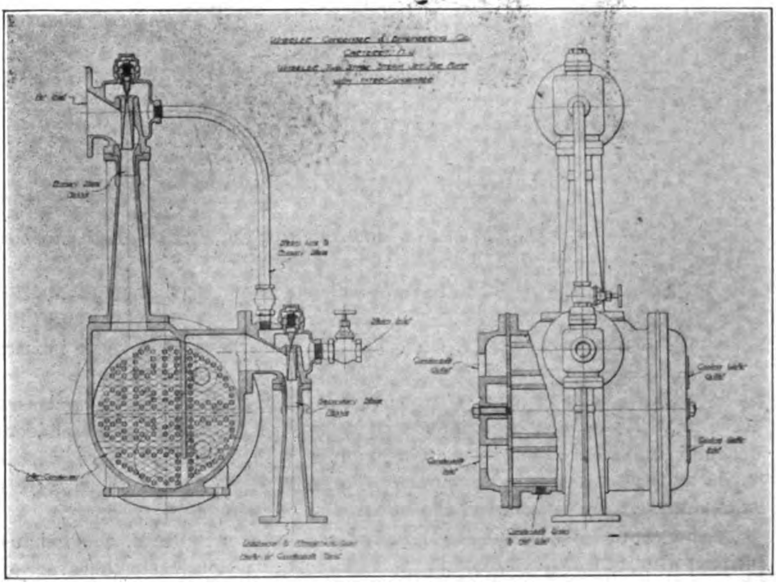

FIG. 17—WHEELER CONDENSER AND ENGINEERING COMPANY STEAM JET AIR PUMP

pressure is used here as with the primary nozzle. The function of the secondary-stage nozzle is to eject air only from the inter-condenser into the atmosphere, a heater, or a condensate tank. When two steam jets operate in series without an intermediate condenser, it is necessary to supply enough steam to the second-stage jet to entrain not only the air brought in by the first-stage jet, but also the steam from the first jet. By condensing the steam from the first stage, the second-stage nozzle has only to entrain the air brought in by the first-stage nozzle.

The intermediate condenser consists of two separate nests of tubes, one to the left and the other to the right of the cast-iron partition. The nest of tubes to the left of the partition provides for four passes, and

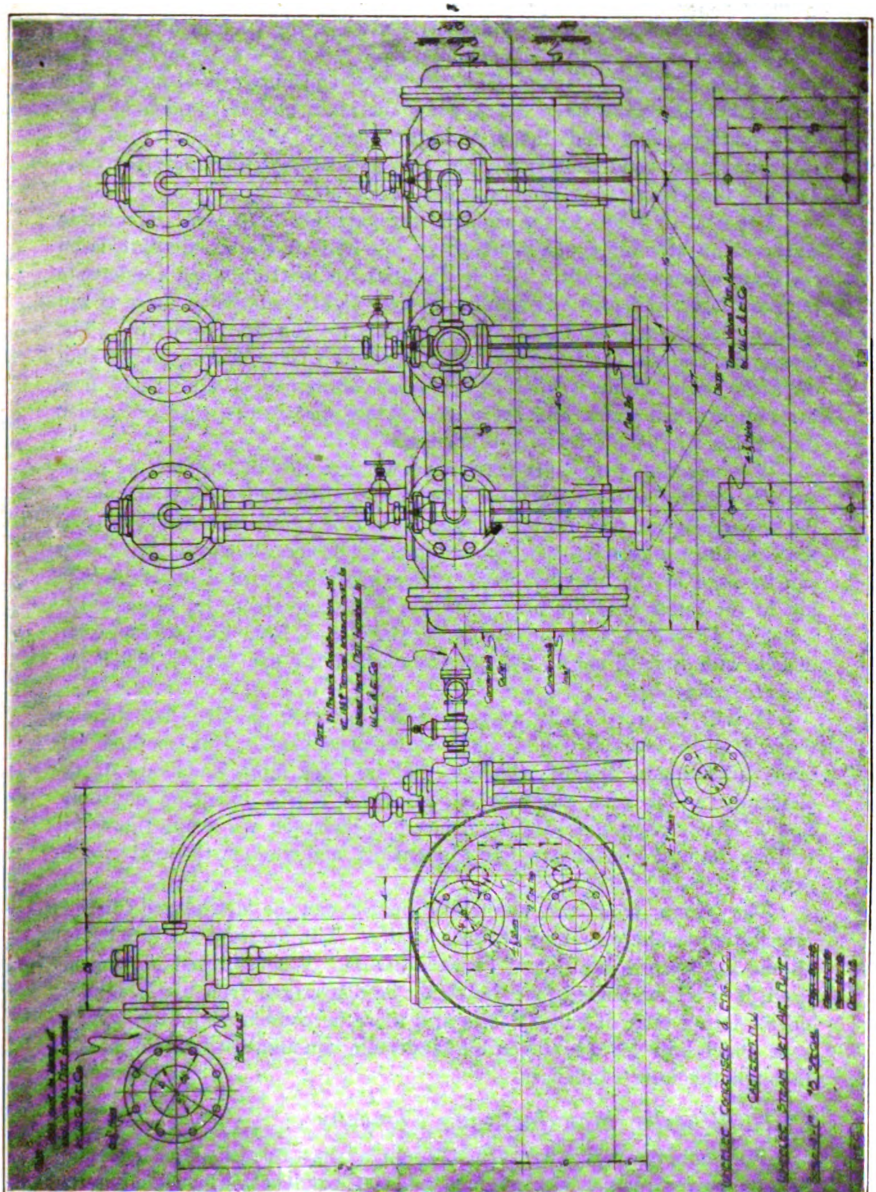

FIG. 18.—WHEELER C. & E. CO. TRIPLE STEAM JET AIR PUMP

contains about two-thirds of the total condensing surface. The condensate from the main surface condenser is used as the cooling fluid in this compartment when used in connection with such a condenser. Consequently the heat in the steam from the first-stage nozzle is absorbed and utilized by the condensate. Even when the main unit is running at only three-quarters load and there is approximately three-quarters of the full amount of condensate available, this quantity is still ample for condensing the steam from the first nozzle.

The nest of tubes to the right of the partition is for raw circulating water in an amount equalling, usually, one-half of the condensate from the main condensing unit. This is essential for starting when condensate is unavailable, and also for running at very light loads when there is not condensate enough to enable the machine to function properly. The piping, of course, can be so arranged that this raw water can be shut off after the machine is once in operation, or it may be allowed to flow through it at all times, and serve as a safety measure in case of sudden diminution in the amount of condensate.

In connection with a jet condenser, we provide but one nest of tubes for the cooling water. Here we use the incoming boiler feed makeup as the cooling agent, thus utilizing, as in a surface condenser, the heat from the first-stage steam jet. If the customer so desires, however, raw water can be used in the inter-condenser when operating with a jet condenser, but in the latter case the heat from the first-stage steam jet is wasted.

Fig. 17 shows a single ejector applied to a 2000 kw. surface condenser, and Fig. 18 shows a triple installation for use with a 20,000 kw. surface condenser.

It will be noted that as condensers increase in size, we arrange these jets in multiple on a single inter-condenser. This method has many advantages, one of which is that on very light loads one of the elements can be shut off, with a consequent saving in steam consumption. Thus, when the load is reduced to even 50 per cent, there will still be enough condensate for condensing, and raw water will not be needed.

The steam from the secondary nozzle can be discharged directly into the atmosphere or into an open heater. The pressure on this heater should not exceed one pound gauge pressure. Where closed heaters are used, it is recommended that the steam be discharged from the secondary nozzle into a tank of suitable size and there be condensed by the condensate which has already taken up a certain amount of heat in passing through the inter-condenser.

C. H. Wheeler Manufacturing Company

For more than two years this Company has furnished a large number of power plants with surface and jet condensers in which a new type of dry vacuum pump, called the Radojet, has been used with great success. The first commercial installation was put in operation in No-

vember, 1916, and since that date the Company has installed or has on order about 1000 Radojet pumps.

As this Company pioneered and developed the ejector type of air

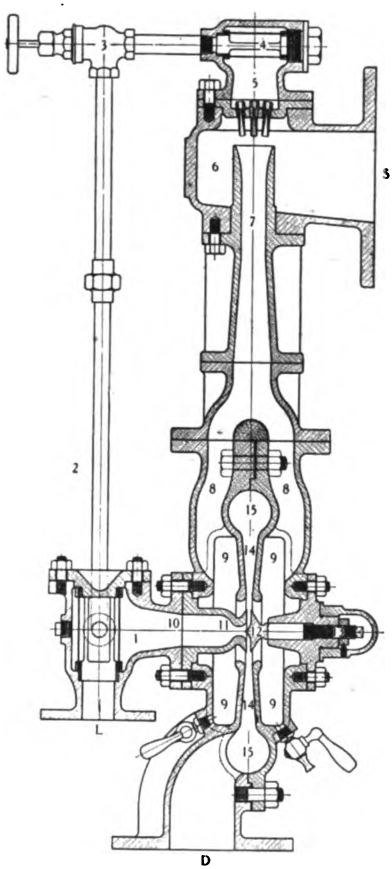

Fig. 19—C. H. Wheeler Company Radojet

pump for land practice, a short description of the Radojet will be given.

This Radojet is illustrated in Fig. 19. Its principal characteristic is the use of steam jets for the removal of air. It consists of two steam ejectors working in series; the upper ejector called the first stage, and the lower, the second stage.

Steam is delivered through strainer 1, pipe 2, auxiliary steam valve 3, strainer 4, expansion nozzles 5, across suction chamber 6, of the first stage ejector, which is in communication with the condenser through the suction opening "S."

The steam expands in the nozzles, leaving with a very high velocity, and, while passing across suction chamber 6, entrains the air and vapors to be compressed.

The mixture passes into the diffuser 7, from which it is discharged at higher absolute pressure than that of the air entering at "S," into a double passage 8, communicating with the suction chambers 9 of the second stage. These two suction chambers 9 are annular, giving the commingled fluid a large entrainment surface.

Steam is simultaneously delivered through the strainer 1 into passage 10, which communicates with the annular expansion nozzle formed between two circular discs 11 and 12. Disc 12 may be adjusted toward or away from disc 11 by the adjusting screw 13 to vary the cross section of the nozzle passage, thereby changing the expansion ratio of the steam.

The steam delivered radially by the annular nozzle 11 and 12 expands, leaving it as a jet of high velocity in the form of a sheet. In passing across the suction chamber 9, it entrains on both sides of the sheet the commingled air and steam coming from the first stage and carries them into the annular diffuser 14, thereby compressing the mixture to atmospheric pressure and discharging it into casing 15 which has the discharge opening D.

The mixture discharged at D may be delivered to a small tank supplied with fresh water for boiler feed or directly into a vented open feed water heater, the steam contained in the mixture being condensed and returned to the boiler.

The steam consumption of the Radojet compares favorably with that of the rotative dry vacuum pump, and its thermal efficiency is practically 95 per cent, as nearly all the heat contained in the steam used for compressing the air and vapors is utilized to raise the temperature of the boiler feed water, the losses due to radiation being practically negligible.

The operation of the Radojet is simple. It has no moving parts nor valves, and does not require lubrication or attention during operation. It is noiseless. Repairs, even after long periods of operation, are not necessary; therefore the operating expense of the Radojet is lower than that of any other type of air pump, and, in addition, the weight and space occupied are very small.

In small surface condenser installations two Radojets are generally provided, each being of sufficient capacity to produce the required vacuum with a normal air leakage in the system. This gives an absolute assurance against shut-downs, due to unexpected leaks, which is feasible

at a small expense only with the Radojet, on account of its small size and absence of foundations.

The amount of air leakage in any condensing equipment is a very variable quantity. Tests on a number of 25,000 square feet condensers indicate air leakages of 3 to 13 cubic feet of free air per minute. A 45,000 kw. unit recently tested showed air leakage averaging 6 cubic feet per minute. With displacement air pumps it is necessary to provide for the maximum leakage by an unnecessarily large pump. With the Radojet system this is accomplished by using multiple units, which

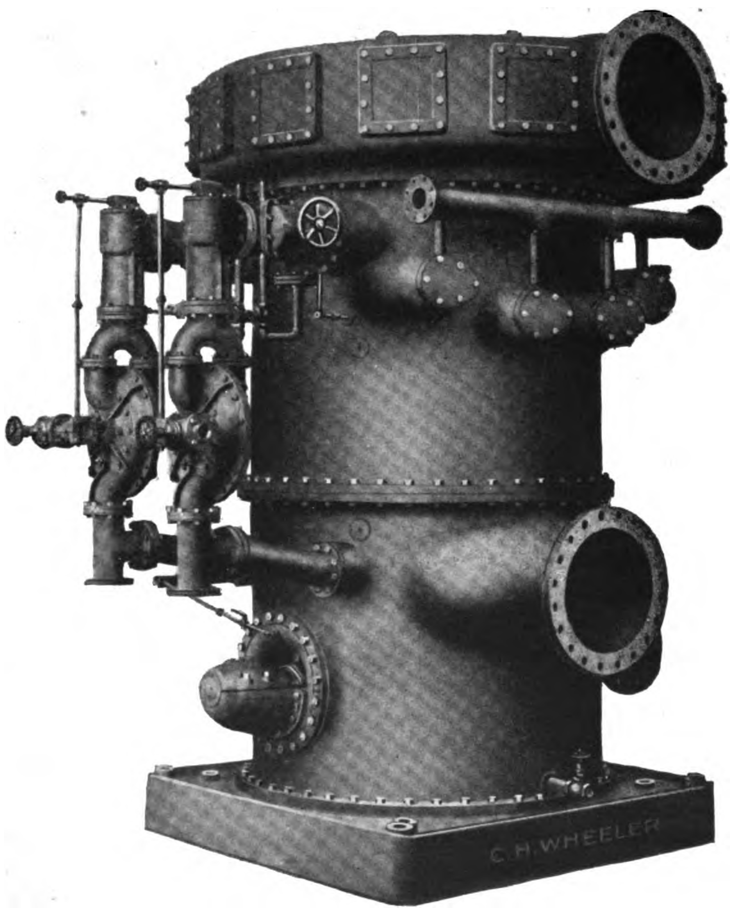

Fig. 20—C. H. Wheeler Company Jet Condenser with Radojets

arrangement provides two very desirable features; absolute assurance against shut-down from the air pump by having one or more reserve units; units to be operated with maximum steam economy, only enough pumps being in service to take care of the existing air leakage. This arrangement of multiple units also gives an exceptional method of controlling the maintenance of the vacuum, for each pump has a definite air removal capacity and the necessity for an additional pump indicates a change in air leakage which might mean an investigation.

The applications of the Radojet to low level jet or barometric condensers have also been numerous. On account of its many advantages, it has been used in connection with condensers of this type.

It is operated independently of the removal pump, which makes the starting of the condenser easy and rapid and which also permits the removal pump a larger range of speed according to the variations in the discharge head. An installation of this character is shown in Fig. 20.

In addition, we also manufacture the Radojet with a surface condenser between stages, which may be used in power plants where conditions do not permit the proper utilization of the exhaust steam and where a further reduction of steam consumption is desirable.

During the past two years the shops and manufacturing facilities have been practically doubled to provide for the increased demand for this Company's products, which include, in addition to surface, jet and barometric condensers, Radojet and Rotrex vacuum pumps, circulating and condensate pumps, feed water heaters, cooling towers and all condenser auxiliaries.

Worthington Pump and Machinery Corporation

The Worthington Pump and Machinery Corporation has sold two types of steam air ejectors, both with and without inter-condenser, and is prepared to furnish inter-condenser, either of the jet or surface type, as special conditions require.

These ejectors are the result of years of study and experiment both in the shop and in service. This company is now constructing a number of two-stage ejectors as well as a multiple unit consisting of two first-stage and one second-stage ejectors.

The first of these multiple equipments which is nearly completed is shown in the accompanying illustration. For this particular installation it was necessary to have the first stages horizontal and the second vertical.

The Worthington Company is not offering the air ejectors to replace the present reciprocating or hydraulic vacuum pumps, but as an alternate so that the customer may select the type which best suits his conditions.

The steam ejector has been in use for power vacuum work for some years, but no earnest attempt has been made to introduce it in land work. The unusual conditions during the recent war forced the more general installation of ejectors for marine use than would have been the result in normal times. The results have been of varying value, and a discussion upon this subject before a marine society would undoubtedly bring forth quite different views. Ejectors did not supplant the positive displacement of piston type of twin vacuum pumps for navy use—in fact, this company supplied upwards of 600 pumps of that type for the United States Navy during the period of the war. We are still selling this type to the navy and the various yards. The ejector was, however, as satisfactory as could be expected under the conditions. In marine work, both space and weight are of importance and the heat balance is quite different from that in land stations. There are stationary plants where it will undoubtedly work in to good advantage, but there are a great many points to be considered and a new set of complications not ordinarily encountered. In the first place, the steam ejector has an extremely low mechanical efficiency which, to some extent, is offset where the total heat of its discharge can be utilized. The misleading claim is sometimes made that the steam ejector has an advantage over the hydraulic vacuum pump in that it saves the heat equivalent of the mechanical work performed. The steam ejector has such a low mechanical efficiency that the saving so effected is negligible in the station economy.

The two stage non-condensing ejectors shown in the illustration were guaranteed to maintain a vacuum corresponding to 2 in. absolute pressure when operating upon a shop test handling free air through an orifice (this corresponds to compressing this amount of air from 2 in. to 30 in. absolute) when supplied with 1650 lbs. of steam per hour—equivalent to approximately 800 lbs. for a condensing ejector which is a fair average for different types of ejectors.*

The actual adiabatic work performed is 4.16 h.p., having a heat equivalent of 10,595 B.t.u. per hour and a steam consumption of 192.2 lbs. of steam per hour, per h.p. of work performed on dry air orifice test. Steam ejector performance should properly be based upon a dry air orifice shop test as the determination of air actually handled in service with the steam ejector would be a very complicated matter—but the orifice capacity must not be confused with the capacity in actual service; for example, with a suitable air cooler in the main condenser, cooling the non-condensible vapors approximately 10 degrees when the condenser is maintaining 2 in. absolute, this would give a steam vapor pressure of 1.5 in. and a partial

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* Note.—Tests now in progress would indicate the probability of substantial improvement in economy for the latest condensing ejectors.

air pressure of 0.5 in. in the mixture going to the steam ejector, so that the weight of air handled in actual service would be but one-quarter that of dry air at the same total pressure in orifice test—for the same steam consumption—correcting for temperature the actual volume of free air would be only 3.84 cu. ft. Correcting for the weight of the saturated mixture, the work of adiabatic compression would be only 2.89 h.p. The

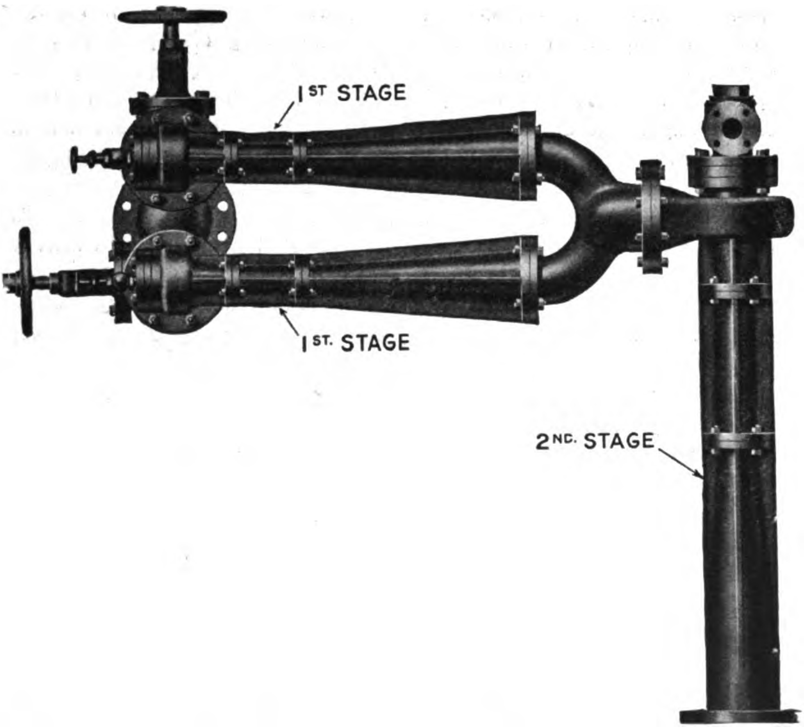

Fig. 20a—Worthington Two Stage Ejector with Two Ejectors in the First Stage

maximum allowance for air leakage on a 2000 k.w. unit, say at 30,000 lbs. steam per hour, is 4 cu. ft. free air per minute, which can also be taken as the minimum leakage for a 25,000 k.w. unit at 300,000 lbs. steam per hour. Such a unit operates with a leakage of between 4 and 10 cu. ft., which may be reduced to 3 when put in condition, or as low as 1 cu. ft. in special instances. The evaporative heat for 30,000 and 300,000 lbs. steam per hour is 30,000,000 and 330,000,000 B.t.u. respectively—

evaporating at 200 lbs. and 150 degrees superheat from 212 degrees fahr. The percentage of saving by utilizing the heat equivalent of the actual ejector work for 4 cu. ft. varies from 0.023 to 0.0023 of 1 per cent, which is a station economy not worth discussing.

The steam ejector requires more steam than the hydraulic vacuum pump and several times as much steam as the rotative dry vacuum pump. The hydraulic vacuum pump may occasionally be installed to take its supply from the suction inlet tunnel and deliver to the discharge tunnel, but in practically all of the Worthington installations the cooling water is pumped over and over again, thus saving in the pumping power required and calling for only a small percentage of make-up, which in some cases might be used to advantage as make-up for the feed. The hydraulic vacuum pump recovers in its hurling water 80% of the heat equivalent to the actual work performed, but even at this rate, the increase in temperature of the hurling water is only at the rate of 1 degree in anywhere from 5 to 10 or 15 minutes, depending upon the percentage of air present in the vapors.

The purchasers' requirements as regards heat balance must also be considered in selecting the type of vacuum pump. In some cases the company has been limited to an amount of exhaust from the condensing and other auxiliaries which would raise the feed to 125 degrees and in one case to 110 degrees fahr. This has compelled consideration as to whether the condensing auxiliaries should be driven by motor and such small amount of steam as required to heat the feed taken from some stage of the main turbine or whether certain of the auxiliaries should be steam driven and exhaust into an intermediate stage of the main turbine. In any event, such conditions cut out consideration of the steam ejector.

At the present time, after long and careful operating experience, the wet and dry system has been practically universally adopted and the air withdrawn from the condensing system is thrown away while the condensate freed from this air is pumped over and over again through a closed system. A better vacuum is obtained in this way and in case of trouble it has been possible to shut down the dry vacuum pump for a half hour or longer without serious fall in vacuum.

In one case, under test conditions the dry vacuum pump was closed for a half hour with loss in vacuum of only 0.3 in. Dry vacuum pumps have lately been built with a heavy fly-wheel to enable slower operation without centering and the range in possible speeds permits an elasticity corresponding to the leakage which cannot be obtained by any form of ejector.

The steam ejector moreover delivers the air taken from the condenser back into the feed water ensuring charging the feed water with air up to its capacity at the temperature and pressure carried. In a paper presented before the National Electric Light Association at Chicago in 1916, curves were given which showed the effect of air upon the performance of the condenser, these curves being based upon actual operating records

taken at random from the records of the New York Edison, Waterside Station, for a period of one year and tests specially run at Detroit Edison to obtain comparative results. In both cases the resultant curve of condenser efficiency was a straight line with slightly different inclinations. Recent observation has confirmed this direct variation in vacuum with air leakage, although it is affected by so many other conditions that no definite law has as yet been worked out which can be generally applied.

BOILERS AND SUPERHEATERS

Boiler Settings

Your Committee has practically nothing to add on the subject of refractories which has been ably covered in previous reports. Brief comment might be made, however, on some recent tendencies in connection with boiler setting design and baffle material.

Proper application and limitation regarding the use of insulating brick in boiler settings are becoming better understood, although there is still much widely divergent practice regarding this matter. The advantages of using this material are fairly well understood and need no discussion. The limitations, if evident at all, occur in that portion of the setting which is nearest the furnace or subject to the highest furnace temperatures and the consequently greatest expansion and contraction strains. There is a feeling on the part of operators who have had experience in this matter, particularly in connection with high boiler ratings, that the walls of the furnace should be built of as few different kinds of material as possible and that the walls should be solid, well bonded and homogeneous. In fact, there is a recent tendency toward building the furnace walls of solid fire brick. Another point which may be grounded on fact is that until some more satisfactory refractory material is developed, it may be necessary to depend to a certain extent on the radiation of heat through the furnace wall to cool and preserve the furnace lining. There are many places about the boiler setting other than around the furnace, however, where insulating brick can be used to advantage and the practice may be generally recommended.

There has been some experimental work in progress regarding the materials used for baffles. One company reports a trial installation using transite for the rear baffle of a Stirling boiler. Another company for the vertical baffling of Babcock & Wilcox boilers has standardized on two layers of baffle bricks with asbestos millboard in between. Still another company for a similar type of boiler has adopted the usual flame plate and baffle brick type of construction, but with one layer of brick and then 2½ inches of asbestos cement applied wet. There are several patented types of baffles on the market, a few of which seem fairly promising, but have not as yet demonstrated their practicability and durability under all classes of service. There does seem to be, however, a demand for a baffle which, compared with the usual type, is tighter, more readily renewed or repaired and can be placed at any desired angle with the tubes.

Methods of Preserving Furnace Side and Bridge Walls

The problem of how to design the side and bridge walls of the boiler furnace so as to necessitate a satisfactory minimum of brick work maintenance and boiler outages, is one on which considerable progress has been made, but the solutions offered so far have been more in the nature of relief measures than fundamental solutions of the problem. The present day demand is for a furnace lining which will withstand the high furnace temperatures and blow torch action, the constant heating and cooling effect, and the abrasive action of the fuel bed. A furnace lining to which clinker formations would not adhere is very much to be desired, but if this is impossible, it must have the mechanical strength to withstand the necessary barring or breaking off of the clinkers. Previous committee reports have discussed progress along the line of refractories to meet these requirements, and it is believed by your present Committee that there is comparatively little to be added at this time. There are, however, a considerable number of various and diversified means in use for preserving furnace linings, and a brief enumeration of these, together with suggestions as to conditions under which they may be tried out, may be of general interest.

Ventilated Walls: Several patented applications of the plan for admitting air through the furnace walls in such a manner as to keep the walls below a harmful temperature, are in use. One of these patented arrangements provides ducts in the side or bridge walls connected with the forced draft system for the stoker. The air in these ducts is released into the furnace through small interstices in the usual fire brick lining of the furnace. This cooled air is applied only to the lower portions of the side walls and bridge walls, or in general, where the action against the brick work is most severe. Another very similar plan uses hollow blocks of refractory material for the furnace lining. The hollow tile form the ducts which are tied in with the forced draft system, and the air is released into the furnace through very small holes cast in the hollow blocks. Schemes of this nature have been used with some success on underfeed stoker installations, and in many instances have prolonged the life of the furnace lining very materially. It is said by users of these methods that the amount of air passed into the furnace for this purpose has no harmful effect on the furnace efficiency.

Special Refractory Materials: A refractory manufacturer in the East has put out a fire brick the chief constituent of which is carborundum. This brick has been used to a limited extent for furnace linings and not without some success. It seems to fulfill to a very marked degree the requirements of a furnace lining, but the cost is necessarily very high compared with the usual run of fire brick prices, and its possible use is, therefore, very limited.

Steam Jets: The use of a steam jet beneath the grate to "soften" the clinkers is a very old custom and the principle is used quite extensively in connection with stoker operations at the present time. As a side wall preservative, the method used is to run a perforated ¾-inch or 1-inch steam pipe along the grate at the side walls and use a constant flow of live or exhaust steam. Since the principle involved is that the steam cools the flame temperature to a point below the fusion temperature of the ash so that no clinker is formed, the amount of sidewall which can be protected depends on the vertical distance to which

this cooling effect can be carried, which is, of course, limited. For the more moderate conditions of furnace operation, this method is often quite effective. A necessary precaution in using this method is to see that the steam does not escape with such a velocity as to cause a blow torch action on the grate or side walls.

Water Cooled Ledge Plates and Water Backs: On certain types of stokers, as for example, chain grates, the water cooled ledge plate is used quite extensively to prevent the formation of clinkers on the sidewalls and the abrasion due to the moving fuel bed. Water cooled cast iron bridge wall sections are also sometimes used with varying degrees of success. A sure and positive water circulation is necessary with these devices; otherwise, they become very troublesome features from an operation as well as maintenance standpoint. Air cooled cast iron bridge wall sections through which the air for the stoker is first passed, have been used with moderate success in a very few instances. Cast iron ledge plates have been used in connection with underfeed stokers and are reported to give fair satisfaction, if provided with fins or ribs in such a manner that a protecting layer of ash is held between the heat of the furnace and the iron.

High Temperature Cements: There are on the market a number of high temperature cements sold under various trade names. These cements are used for laying up furnace walls, for washing completed furnace linings and arches; also for pointing up furnace linings, arches, etc. Many widely varying reports may be obtained regarding their value as a preservative. In general, but not without exceptions, their usefulness is confined to the smaller boiler unit sizes or where furnace conditions are not severe.

Boiler Forcing Rates

In recent large central station designs, maximum boiler ratings of from 250 per cent to 400 per cent have been used in the basic calculations and carried out to a practical conclusion in the plants when put in operation. This tendency towards higher boiler ratings in modern new plants has led many operators to

feel that boilers in general should be operated at much higher ratings than in the past, which in a large majority of cases was perhaps a justifiable conclusion if not carried too far. However, during the past few years there has been much disillusionment of designers and operators regarding the subject of high boiler ratings. A brief discussion of the various factors entering into this subject may be of general interest at this time.

A boiler is often spoken of as being overloaded, when in reality it is the stoker under the boiler which is being forced beyond its proper limit. Generally speaking, the capacity which can be developed by a boiler and stoker unit is limited only by the amount of coal which can be burned by the stoker equipment. Properly speaking, the capacity of the boiler is mainly a question of how high a flue temperature may be tolerated. The extremely high boiler ratings secured in a few notable boiler plants are obtained by very low ratios of heating surface to grate surface. For example, the boiler units of the Buffalo General Electric Company's plant, which are designed to operate at 400 per cent rating, are provided with a ratio of grate surface to heating surface of 1 to 27.3. One of the principal factors involved in high boiler ratings is, therefore, the coal burning capacity of the grate, or in other words, stoker and furnace design.

A restraining influence on the maximum possible ratings is the fact that the boiler and stoker must be designed to operate at maximum efficiency over as wide a range as possible.

The problem of draft loss at high boiler ratings is by no means a small one and is frequently underestimated in connection with increasing the capacity of boiler plants already installed. This may be readily understood when it is considered that the draft loss through a setting increases as the square of the velocity. A boiler having a draft loss through the tubes of .3 inches at rating, would have theoretically, and this is borne out very closely in actual test, 1.2 inches at 200 per cent rating, and 2.7 inches at 300 per cent rating. For this reason users of underfeed stokers are sometimes disappointed in capacity of their boiler installations due to the fact that the stack or fan does not provide sufficient draft to take the gases away from the furnace.

The character of the boiler feed water may readily become a limiting factor in boiler ratings developed, and, as a matter of fact, this is not infrequently the case. This may occur either through the water containing a troublesome amount of scale-forming ingredients, or through the presence of ingredients which cause it to prime or foam. As a general proposition, extremely high boiler ratings are desirable only in connection with plants equipped with surface condensers, and even then the small percentage of make up water required is sometimes supplied to the system by means of evaporators. Plants using jet condensers may avail themselves of water purifying equipment, but even under the most satisfactory conditions of water purification a small amount of scale may be deposited. The salts left in the water sometimes tend to aggravate any normal priming tendency, thereby limiting the possible ratings developed.

A questionnaire sent to members of the Prime Movers' Committee, representing some of the largest central stations in the country, developed the fact that the normal and maximum forcing rates for boilers in these plants averaged 140 per cent and 200 per cent respectively. Central stations, generally speaking, have to provide steaming capacity for a certain annual peak, which may be of very limited duration. The highest boiler ratings available are used in the estimates for steaming capacity during these periods. During the balance of the year, there is ample boiler capacity and the problem of how to handle the load with safety and maximum economy becomes an operating problem only.

Cleaning External Heating Surfaces

Although there has been little or no improvement during the past year in methods of cleaning external heating surfaces, there has been a very broad movement on the part of operators toward the use of mechanical soot blowers. This movement has doubtless been aided by difficult labor conditions, which have made it almost necessary to resort to mechanical methods of soot removal. Aside from this point of view, however, there is a very general feeling on the part of operators that properly selected soot blowing equipment makes a highly profitable in-

vestment, notwithstanding the fact that this apparatus is not regarded as being wholly satisfactory under severe operating conditions. The various manufacturers have been making minor improvements from time to time in their equipment and methods of installation, which for very moderate boiler ratings may now be regarded as being reasonably satisfactory. Where fairly high boiler ratings are developed, some trouble is encountered in maintaining the soot blower elements located nearest the furnace, regardless of type of construction used, and care is necessary to locate these elements so that they will not be subjected to a destructive heat. Care is also necessary to see that there is no jet action of the steam against the tubes. Some trouble has developed from the use of valves which were not suited to the steam conditions in which they were used. No mechanical soot blower has yet been devised which will remove the clinker forming on the lower rows of tubes, and it is still necessary to remove this by means of a hand steam lance or by the use of scrapers.

There are a few types of mechanical soot blowers which blow jets of steam horizontally across the tubes from the side of the boiler and operate in much the same manner as a hand steam lance. These types are fairly satisfactory for boilers of a width sufficiently narrow so that there is no tendency to bank the soot at the far end or to leave any soot unremoved.

Priming of Boilers

From the operators' standpoint, the priming of boilers is often a troublesome and sometimes a very persistent and harmful malady. To treat the subject fully and in all of its phases is beyond the scope of this report. In fact, the subject is one which is full of conjecture and unproven theory even among those who have made it a special study. It is proposed here merely to point out to the operator some of the things he should investigate in case of suspected or known boiler priming.

It does not always happen that the fireman or water tenders know when a boiler primes, as there may be no evidence of it in the glass. In fact, the boiler room operators may be quite positive that the boilers do not prime. The real test lies in the quality of the steam leaving the boiler, or in the tem-

perature of the steam leaving the superheater. A very good method of providing a check on a boiler is to equip it with a recording thermometer on the steam outlet from the superheater. Priming will be indicated by sharp fluctuations in the superheat temperature curve. Frequently a small leak in the steam line between the superheater and main steam header offers a sufficient tell tale to show whether or not the boiler is priming badly. A wet steam leak is visible, whereas a superheated steam leak is invisible.

Internal Inspection

An internal inspection of the boiler is probably the first and simplest thing which can be done. If there is oil or organic matter in the feed water, it will be evident around the water line inside of the drums. The dry pipe, if any, and in fact the whole steam space, should be examined carefully and any peculiarity with regard to the presence or absence of scale or mud noted.

Concentration Test

If the internal inspection of the boiler shows priming, but without any clue as to the cause, it may be that the boiler is not being blown down sufficiently. The following method of determining the concentration of the water in the boiler is recommended by the Babcock & Wilcox Company and is here quoted with its permission:

A complete analysis of the water in the boilers is more or less expensive and takes considerable time. Therefore, the following method is substituted as a standard operating check which can be made periodically in a very short space of time and which gives a close enough approximation to be satisfactory.

The method following will determine the amount of sodium chloride in the boiler water and requires the following glassware and solutions:

1 50 cc burette
1 100 cc pipette
1 500 cc Erlenmeyer flask
1 burette stand
1 liter 10th-normal silver nitrate solution
1 bottle potassium chromate indicator.

The method of procedure is as follows.

Obtain a pint sample of water from either the water column or the blow-off of the boiler. With the 100 c.c. pipette withdraw 100 c.c. of water to be examined by suction with the mouth.. The water level

should stand exactly at the scratch mark on the stem of the pipette. Deliver this sample into the 500 c.c. Erlenmeyer flask.

Then fill the burette with the 10th-normal silver nitrate solution and carefully note the reading.

Add two or three drops of potassium chromate indicator.

Grasp the Erlenmeyer flask by the neck in the left hand and give it a whirling motion, at the same time run in the 10th-normal silver nitrate by operating the stop cock of the burette with the right hand. The silver nitrate should be delivered slowly drop by drop, and with the first indication of a change of color to a faint blood red tinge, the addition of the nitrate should be stopped. Sufficient silver nitrate should be added so that the body of the liquid as a whole remains a permanent red color.

Again, carefully note the reading on the burette and the difference in volume in terms of c.c. of silver nitrate used will represent the sodium chloride content of the water. To express this value in terms of grains per gallon, each c.c. of the silver nitrate is equivalent to 3.38 grains per U. S. gallon of sodium chloride.

10th-normal silver nitrate is of a strength equal to 16.966 grams of silver nitrate per liter of distilled water.

The above method is reliable only when the water to be tested is neutral or faintly alkaline. It is, therefore, frequently necessary to bring the water to be tested to a neutral point, or very slightly alkaline point before making the silver nitrate addition. For this purpose, methyl-orange is used as an indicator, and depending upon whether the water is alkaline or acid, an addition of either nitric acid or caustic soda is made drop by drop until the water is a faint straw color. The subsequent determination is then made as described above.

The amount of concentration which is good practice is variable, and it is impossible to give any certain definite concentration and say that all boilers should be operated with a concentration just below such a point. The best method is to determine at the specific plant what concentration can be carried under the load and water conditions at that plant. Then see to it that all the boilers are maintained with a concentration below such a point.

In general, the total solids in a water will bear a certain constant ratio to the sodium chloride content, and one or two complete analyses of boiler water samples will determine such a ratio. The above check with sodium chloride can therefore be used as an approximate method of checking for total solids in the boiler.

Boiler Design

Ordinarily, unless there is some other very obvious cause for priming which can be removed, the above concentration test offers a very satisfactory method of avoiding priming of boilers. However, it may be found that the amount of blowing down

required is so great as to be practically prohibitive. In such a case, it might be desirable to study the probable action of the water and steam in the boiler itself, with a view to inserting baffles in the steam drum, changing the dry pipe design, or as has been done in several instances, making a change in the point of steam offtake. It sometimes happens that a single change or addition as indicated above permits the boiler to be operated without an undue amount of blowing down.

General

There are various other features which should be investigated, such as source and analysis of feed water, chemicals used, purifying method of introducing the feed water into the boiler, and, in fact, any clue which looks as though it might lead to something bearing on the subject. There are some very divergent opinions as to which chemical ingredients aid in priming and which do not, particularly soda ash. It is fairly generally agreed, however, that the presence of oil or organic matter, together with an excess of soda ash or magnesium salts, may bring about very bad priming conditions. Surface blow-offs are sometimes used with success under certain water conditions, but as a rule these devices are troublesome to maintain and operate and the conditions requiring them can better be remedied outside of the boiler.

Feed Water Regulators

Recent labor conditions have turned the attention of operators toward the subject of feed water regulators, with the result that for average boiler plant conditions and for plants containing more than three or four boiler units, a wise selection of feed water regulators may now be regarded as standard practice, although there are possible exceptions in which the use of regulators may be inadvisable, such as, for instance, where extremely fluctuating load conditions prevail. The manufacturers of this class of apparatus have made some progress towards a better understanding of the requirement for automatic feed water regulation. Generally speaking, the most satisfactory type of regulator is one which does not aim at a constant water level, but which takes advantage of permissible variations to aid in caring for fluctuating steam demands on the

boiler. Some operators claim an advantage in added reliability for the positive mechanical connection between thermostat or float and the regulating valve as compared with the pilot valve and pressure operated diaphragm type. The former type, however, is at a slight disadvantage in that it does not allow the same latitude in locating the feed regulating valve. Recent improvements have been made in the design of floats on certain types of regulators which make this class of regulator less subject to the criticism of unreliability than heretofore.

With the advent of modern boiler plant improvements and the higher grade of labor necessary to maintain and use them properly, operators do not regard the necessary care and maintenance of feed water regulators as being as much of a burden as heretofore.

Superheaters

The matter of relative attention given to boilers and superheaters is one which deserves brief mention. The superheater is frequently overlooked by the boiler cleaning and repair crew for the reason that it seldom really needs any cleaning or repairs. It is safe to assert that the superheater should be as carefully inspected and watched as any other portion of the boiler. It should be opened up and thoroughly washed each time the boiler is out of service for general overhauling. The hand hole plates should be inspected for leaks and loose dogs. The exterior surfaces should be freed of soot or slag formation. The internal condition of the superheater may be regarded generally as being a very good indicator of wrong conditions within the boiler. If the superheater shows signs of mud or scale or other foreign matter, it is time corrective means were employed to remedy these conditions within the boiler.

The question of pressure drop through superheaters is one which frequently causes operators some little concern, usually for the reason that the plant designers make an insufficient allowance for pressure drop between the boiler proper and the turbine. The operator finds himself faced with the problem of how to reduce this over all pressure loss. A superheater is necessarily designed to produce a certain amount of pressure loss at low ratings; otherwise the steam might short circuit through the nearest tubes and permit the farthest ones to

become burned. Superheaters are usually designed to operate at rated boiler capacity with from ½ to 1½ lbs. pressure loss, depending on the maximum rating to be developed, and for this reason operators should be cautious about removing the cores without first obtaining the approval of the manufacturer. Since the pressure loss increases as the square of the velocity, a one pound loss at rating would mean four pound loss at 200 per cent rating, and nine pounds loss at 300 per cent rating.

In connection with a discussion of superheaters, it might be well to point out that the superheater as such is a very efficient piece of apparatus, but as a boiler or evaporator, it not only becomes a source of loss through loss of superheat, but may be the cause of high maintenance as well. It may be interesting to note that at 200 pounds pressure and 100 degrees superheat, one per cent of moisture in the steam entering the superheater causes a loss of 17 degrees of superheat. This discussion brings to light the need for taking every possible precaution to insure steam as nearly dry as possible entering the superheater. Since dry pipes are used solely for this purpose, and in view of the widely varying practice regarding them even among boiler manufacturers, your Committee recommends first, that manufacturers be encouraged to make further investigation with a view to standardizing regarding dry pipe practice, and second, that operators give the need for dry pipes very careful study and consideration with a view to submitting their findings to the manufacturers in your Committee's report next year.

The replies to a questionnaire on superheater practice were generally unsatisfactory and indicated a lack of accurate information as to superheater characteristics. Apparently the superheater continues to be an adjunct fitted to a more or less inflexible design of boiler, and it is felt that there should be a closer co-ordination of superheater design with boiler design.

Coating Exterior Surfaces of Settings

The matter of reducing air infiltration through boiler settings by means of special preparations to be applied to the exterior surfaces of the settings has received wide attention. Various preparations are on the market and they are composed mostly of coal tar or asphaltum and asbestos. This material is applied usually with a trowel to a thickness of about an eighth

of an inch, while the setting is warm but not hot. In order to be most effective, frequent inspections of the settings are necessary, pointing up cracks and renewing the coating where needed. For the average boiler setting, these coatings are very effective, particularly if the setting is old or natural or induced draft is used to burn the fuel. Some operators find an oil paint preferable, especially where the settings are in good condition and fairly new. In plants equipped with underfeed stokers and thick solid fire brick walls, the claim is made that no setting paint at all is necessary for reasons other than appearance or lighting effect. In regard to this whole subject of preventing the infiltration of air through boiler settings, it may be well to point out that the average boiler setting contains a large number of doors and openings of various kinds, and inattention to the tightness of these or the way they are closed may cause many times the air infiltration through unprotected brick walls.

Uniform Boiler Law

Early in the year 1916, the American Uniform Boiler Law Society was formed for the purpose of presenting the Boiler Code, as formulated by the American Society of Mechanical Engineers, to the governing bodies of all the States and Municipalities, for its legal adoption. The Administrative Council of the Society is composed of a representative from each of the following industries:

American Boiler Manufacturers' Association
National Association of Thresher Manufacturers
National Boiler and Radiator Manufacturers' Association
Low Pressure Steel Boiler Manufacturers
Water-tube Boiler Manufacturers
Locomotive Manufacturers
Steam Shovel Manufacturers
Hoisting Engine Manufacturers
Boiler Insurance Companies
National Electric Light Association
Boiler Material Interests.

The funds for carrying on the work of the Society are derived entirely from voluntary contributions.

Our organization believes in the preservation of life and property and we seek to protect the life and property of every man, woman and child in the United States by having uniform rules legally adopted, that will make boilers more safe. There is nothing in commercial life today that has been neglected more than the construction of boilers.

Today, a boiler can be built to fit almost any condition as to price. We are menaced by poor construction which is augmented by the desire of the builder to meet the ideas of his customer as to prices—this condition should never be allowed to exist where human life and the destruction of property are involved. On the other hand, if all manufacturers are compelled by law to build to a fixed standard, it lessens the responsibility of the purchaser, for no matter who makes the price, if the boiler is built according to law, he is assured of a good boiler, his only concern being in tabulating the price on the boiler so far as safety is concerned, and selecting the type of boiler best adapted for his needs.

The following States and Cities have adopted the Code and are accepting boilers built to the A. S. M. E. specifications:

States		*Cities*
New York	Wisconsin	Detroit, Mich.
New Jersey	Minnesota	Erie, Pa.
Pennsylvania	Ohio	Kansas City, Mo.
California	Indiana	St. Joseph, Mo.
Michigan	Allegheny County, Pa.	Philadelphia, Pa.
		St. Louis, Mo.

The General Engineering Depot, Washington, D. C., specifies that all new boilers be built in accordance with the A. S. M. E. Code.

It will be interesting to know that ten Bills for the legal adoption of the Code have been or will be introduced during the 1919 sessions of the State legislatures. The Society's campaign has been one of education, publicity and cooperation. In no State has the Code been defeated on its merits. The arguments in its favor have everywhere prevailed and in no State has it been successfully attacked.

STOKERS AND GRATES

It is believed that the most important developments in the underfeed type of stokers, are the power dump grates and the clinker grinders, both of which are coming into more general use. Of these, it is believed that the clinker grinder is the more important, as it eliminates all dumping with consequent changes in furnace conditions and loss of boiler capacity during the dumping period, and reduces the combustible in the ash to a very low figure.

The Westinghouse Company has developed three types of power dumps and a rotary clinker grinder. The American Engineering Company has developed a power dump and a rotary clinker grinder; the Sanford Riley Stoker Company has developed a rocker dump which also acts as a clinker crusher; these are described more fully in the manufacturers' statements.

Clinker Grinders. Besides the grinder developed by the American Engineering Company, several of the member companies have installed grinders of more or less special design, with which some very excellent results have been secured. It is essential in these installations to provide sufficient depth of ash above the grinder to protect them from the hot clinkers; and to proportion the opening leading down to the grinders so that clinkers will not bridge across this opening and prevent the ash from getting down to the grinders. The successful solution of this problem will greatly improve the operation of these stokers, increase the efficiency and reduce smoking.

Chain Grates. The forced draft type of chain grate is being used more extensively than heretofore, and has been used successfully in burning low grade fuels, high in ash. Improvements in furnace construction and draft control have materially improved operation.

In reply to a questionnaire sent out by the Committee, some general data were collected in regard to the methods used by the various companies, which may be of interest.

Seven of the large companies control the draft over the fire by hand, each boiler being controlled individually. One company controls the dampers of four or five boilers together by hand. Two companies use automatic means for maintaining the draft over the fire constant.

We found quite a diversity of practice in regard to the method of controlling the air pressure under the grates. The most popular system is the well-known method of having a number of forced draft fans discharging into a common duct system, with the speed of the fans controlled by hand and the dampers to the individual boilers controlled by hand. One company in addition to varying the speed of the fans also varies the number of fans in operation. When the type of fan employed is such that the volume of air increases as the pressure decreases, this method is worthy of notice.

A few of the companies use individual fans for each boiler, the speed being controlled automatically by the steam pressure. One company has installed a system in which all the forced draft fans are controlled from one point by means of remote control, while another company uses constant speed with automatically controlled dampers at the boilers.

In cases of large boiler units, the practice of installing individual forced draft fans for each unit has been adopted by several large companies. In selecting fans which are to discharge into a common duct, care must be taken to see that their characteristics are such that they will operate in parallel satisfactorily.

On underfeed stokers, member companies have burned successfully a very wide variety of fuel. In certain cases modification of the stoker has been found to improve the operation. In general a high volatile bituminous or semi-bituminous coal with a high melting point ash and not too great a caking tendency is preferred for this type of stoker.

Chain grate stokers with natural or induced draft are giving especially satisfactory results with low grade fuels containing a high percentage of ash. Coals which have a marked tendency to cake are apt to give trouble due to the formation of a crust which keeps the air from getting through the fuel bed.

Chain grate stokers with forced draft are operating satisfactorily on various types of fine fuel, such as coke breeze, No. 4 Buckwheat, anthracite screenings, culm, etc. Satisfactory operation has been secured under these conditions with the boiler running at from 150 to 250 per cent rating, depending upon the grade of fuel, square feet of grate area installed, etc.

Some of the member companies have experienced difficulty in rapidly increasing the rate at which the boiler was operating after a more or less prolonged banking period. This trouble is especially marked with certain classes of fuel, particularly those which cake or which have a large percentage of sulphur causing the ash to clinker very badly. This trouble is also aggravated in case the stoker is supplied with air from a common air duct and the inlet dampers do not close tightly.

There is an increasing tendency on the part of member companies to sectionalize their stoker drive on underfeed stokers. On some recent installations consisting of thirteen retort stokers, the stoker was divided into four sections, each section driven by its own motor. On one installation of seven retort stokers, the stoker was divided into two sections. One company is dividing its seven retort stokers into three sections and has developed two methods of driving them. In one case they use three 4-speed motors, and in another case one 4-speed motor with three 2-speed power boxes. These methods of sectionalizing the stoker drive enable the operating force to maintain a more uniform thickness of fire across the stoker by varying the rate at which the coal is fed in at different points. If holes develop in the fire, that particular section of the stoker may be speeded up in order to correct the defect.

Manufacturers' Statements

Your Committee is in receipt of statements from the following manufacturers covering developments during the past year:

American Engineering Company

We build. five types of stokers to meet various operating and fuel conditions. In addition to the well-known hand-operated type, the AA6 and AA7 represent the types of which the greatest number are used. Type AA6 is equipped with our patent power operated dump and a moving extension grate of superior design. Type AA7 is similar, with the exception that it is equipped with our patent rotary ash discharge.

Type BA6 is equipped with a much larger retort with triple plungers, one feeding plunger and two distributing plungers, and a power operated dump plate of very large ash storage dumping capacity. This type is becoming increasingly popular, particularly for low grade high ash coals;

it provides for a low normal rate of fuel burning per unit of area, with less clinkering of the coal, and for a large ash storage capacity, so necessary for high ash coals. The large amount of fuel storage in the retort makes it extremely flexible under varying conditions and also permits of an extremely high fuel burning capacity for limited lengths of time. Type BA7 is similar in design, except that it is equipped with rotary ash discharge instead of power operated dump plate.

All these later types of stokers have shown superior results in the handling of ashes, in the elimination of large clinkers and related clinker troubles. We also find that they burn out the combustible in the ash to a considerably greater extent, and show superior results with regard to quick steaming.

The power operated dump plate eliminates all the hard labor of cleaning bridgewalls, which was formerly experienced with hand dump stokers. It not only cleans the fire quickly, and to a far greater extent than was formerly possible, but also serves to preserve the bridgewall, in that the clinkers are cleaned off before they become firmly fused to the wall.

The stoker is very easy to handle, and any type of fireman can be employed. The stoker equipped with the rotary ash discharge must be operated by men with a higher degree of intelligence than the stoker equipped with power dumps. When properly operated, however, the results more than justify their installation. Manual labor is reduced to a minimum; the amount of carbon shown in the refuse is quite low; long continuous runs of a month or more show less than 10 per cent carbon in the ash, while the boilers were operating at from 150 to 175 per cent of rating as an average.

There are now approximately 60,000 h.p. equipped with the single type of setting, and approximately 80,000 h.p. equipped with the double type of setting of stokers with rotary ash discharge.

One of the most interesting stoker installations of this later type is that of the Monongahela Valley Traction Company. This power plant is equipped with four 1425 h.p. Babcock and Wilcox boilers, under each of which two 14-retort stokers are installed. These boilers will operate up to 400 per cent of rating.

Stokers of the large sizes are being built in constantly increasing numbers. The largest stokers we built last year were four 16-retort, type AA6 stokers for the Acme Power and Light Company of Toledo, Ohio, which are installed under 1375 h.p. Bigelow-Hornsby boilers. The Company has also installed four 15-retort type BA6 stokers under four 1456 h.p. Babcock and Wilcox boilers. The four 15-retort type BA7 stokers at the Essex power plant of the Public Service Electric Company of Newark, N. J., are in point of area the largest stokers we have ever built, and, we believe, the largest stokers that have ever been built in a single type setting. These stokers are installed under 1278 h.p. Babcock and Wilcox boilers, and recently on a month's run operated continuously at a high boiler rating.

Combustion Engineering Corporation

We manufacture two different types of stokers, viz.: the type "E" underfeed stoker for bituminous coal, and the Coxe Traveling Grate with forced draft for anthracite coal.

On the type "E" stoker, no radical changes have been made during the past year, most of the changes consisting of changes in minor details with a view to strengthening or simplifying stoker parts. Considerable experimenting has been done, however, with the firebars and different forms of mechanical movement for actuating the firebars. The firebars experimented with were our standard type of box section firebar with overlapping flanges on the sides, similar to those used on the Murphy stoker. The object of these flanges was to reduce the amount of fine dust which riddles through the grate surface into the auxiliary air chamber, also to increase the area of air space between the firebars. The benefits derived have been considerable, and we believe that it will be only a short time before we will adopt this type of bar for all stokers.

In reference to the different methods for actuating the grate bars, this presents a rather complicated problem on account of the lack of room for a mechanism of adequate strength and wearing surface. We have installed two or three experimental devices making use of bevel pinion and gear for transmitting the reciprocating motion of the piston rod to the rotating motion on the rocker bar, which in turn actuates the grates. The geared lever arm to the end of which the piston rod is connected by means of a variable length link is provided with a number of holes, so that the angular motion of the rocker bar may be varied to suit different kinds of coal. The variable length link provides means for still further adjustment of the relation of the motion of the firebars to the center of the stoker. This arrangement, we believe, has considerable merit, and will be a decided improvement in the stoker, provided a satisfactory material can be found to secure sufficient strength and wearing qualities with the limited size of gears, etc.., it is possible to obtain.

In reference to the disposal of clinker and ashes, with the type "E" stoker this has not presented a particularly serious problem, inasmuch as the clinker formation is along the side walls of the boiler, which are readily accessible through the firedoors in the front wall. What difficulty we have had with the formation of clinker on the bridge wall has been largely eliminated by utilizing the exhaust steam from the stoker cylinder, discharging it in the perforated rear transverse bar adjacent to the bridge wall. This transverse bar directs the exhaust steam jet along the base of the bridge wall, and prevents the formation of serious clinker. What clinker will form does not adhere strongly to the bridge wall, and can be removed easily.

We have not found it necessary or advisable to make use of power dumps. The dump grate that we provide can be handled readily by one man. Inasmuch as the clinker adhesion to the side walls is not difficult

to remove, being readily accessible, we see no prospect of attempting to use power actuated dumping mechanism. Clinker grinders we have tried in the past, but without success. There are some coals on which they can be used satisfactorily, but on the majority of coal we do not think the benefit derived is worth the added cost. In addition, the mechanism is a source of trouble, and we believe it is not a satisfactory adjunct to our stoker.

With hand operated dump plates and under average ratings, the combustible in ash is largely under control of the operator, and if there is sufficient boiler capacity to permit the partial burning down of the fires before dumping, the combustible in the ash is not a serious loss.

In connection with the Coxe stoker, a number of improvements have been made, as in the type "E" stoker, many of which, however, are improvements in details. Among the major improvements, if they can be termed such, we would include the sectional feed plate down which the coal feeds to the grate. This feed plate is provided with a flap door on either end adjacent to the side walls, through which door a slice bar, or chisel point bar may be inserted for the purpose of removing clinker from the side walls. This type of feed plate has been adopted as standard, and is now furnished with all Coxe stokers.

Another improvement is in the safety device or shearing pins, which formerly were used between a hub keyed to the main stoker drive shaft, which hub was driven by the worm wheel through three shearing pins. These pins were of machine steel and were quite expensive and troublesome to replace. In the construction we now use, we provide a shearing coupling consisting of what is practically a flanged coupling with keeper ring on one flange overlapping the other flange. The flanges are drilled for small copper or aluminum pins, so arranged that only one hole can be used at a time. By selecting the proper hole and using either copper or aluminum pins, the driving mechanism of the stoker may be adequately protected from breaking, due to jamming of the grate bars or any other undue loading.

The Coxe stoker, as now furnished, has ball bearing thrusts, with machined worms and wheels, and very little power is required to drive it. Stokers of 120 to 150 sq. ft. will require less than one horse power motor input when driven at the highest ratings of combustion.

Green Engineering Company

We build two types of chain grate stokers, the "K" type for free burning coals such as found in the West, and the "L" type for coking coals such as found in the East. The "K" type has the plain chain while the "L" type has inclined coking plates at the front end.

"K" Type Stokers

Skids. Instead of rolls to carry the chain which forms the grate surface, longitudinal rails or skids are used. These strengthen the con-

struction and, by keeping a flat uniform chain surface, reduce the siftings through the grate to about one-fourth of that obtained with rolls.

Front Tension Take Up. Green chain grates are made with a front tension take up so that chain tension can be adjusted from the operating floor without withdrawing the stoker or taking it out of service. In doing this the desirable feature of spur gearing still remains, and the tension take up does not in any way affect the alignment of gearing.

Rear Damper. A very substantial cast iron rear damper has been installed behind the rear cross girder of Green stokers. This leaves the rear cross girder in the current of air used for combustion, and effectively seals off air admission from other sources and prevents overheating of girder.

Heavier Frame Construction. We use a very strong and rigid frame construction, and the cross members supporting the skids give additional strength to the already rigid construction.

Gate Lifting Device. The gate lifting device has been very much refined by using cut worm and worm gear mechanism for adjustment. The fuel bed thickness can be easily adjusted and an indicator shows the exact depth of fuel bed used.

Arch. The Sealflex arch has provided improved ignition rates. This arch is designed to replace the combination of ignition and combustion arches, and by using longer arches, higher arches and arches set at a greater pitch, some unusually gratifying results have been obtained.

Larger Furnaces. The entire tendency of the time is toward larger furnaces. Furnaces having ten to fifteen cubic feet capacity for each square foot of grate surface are not unusual. This in contrast with the practice of five years ago, when furnaces of from three to five cubic feet for each square foot of grate surface were common, shows the tendency of the times toward setting boilers at a greater height and providing more ample furnaces.

Combination Rear Furnace Wall and Bridgewall. Increasing the height at which boilers are set has made it possible to convert the bridgewall into a rear furnace wall, so that access may be had to the stoker on all four sides. This makes possible the installation of doors through the bridgewall, so that access for inspection of the stoker may be had through it.

Operating Results

The improved furnaces above described have made it possible to operate at from 200 to 300 per cent rating with western coals. Some very high capacities and efficiencies have been obtained with lignites and sub-bituminous coals. The range of these results is approximately from 72 to 77 per cent efficiency at ratings varying from 150 to 225 per cent, carried continuously.

These efficiencies are net and there is no deduction for power to

operate the stoker, or for steam jets to prevent clinker along the bridgewall or on the side walls, or for steam to operate power dumps or any of those deductions amounting to from 3 to 10 per cent with those types of stokers forming clinker and requiring dumping periods.

"L" Type Stokers

Skids and Tension Device

The "L" type stoker has been equipped with skids instead of rails to support the chain, thus reducing the amount of siftings through the chain to approximately one-fourth of the former amount.. The chain tension is taken up from the side, without withdrawing the stoker from the furnace or interfering with the operation.

Cross Girder

The rear cross girder supporting the chain is made of semi-steel and is water cooled throughout.

Front Furnace Wall and Ledge Plates

The front furnace wall along the inclined coking plates is lined with water cooled ledge plates which prevent the adhesion of clinker and insure a uniform fuel feed along the sides. These water cooled ledge plates also eliminate any burning out of side walls.

Pushers

The pushers by which coal enters the furnace have been improved to make them more responsive. The amount of coal entering the furnace can be varied for each foot of width so that uneven fuel beds can be avoided and fuel bed controlled.

Arch

Sealflex arches have made a very marked improvement in "L" type furnaces. Low grade coals can be ignited and burned very rapidly with ignition effects heretofore unapproached in chain grate practice.

Larger Furnaces

The tendency toward larger furnaces has been very marked with "L" type practice. One very ample furnace has 20 cubic feet of volume for each square foot of grate. Its design includes a combination of bridgewall and rear wall, making the rear end of the stoker readily accessible through doors in the bridgewall. The boiler and stoker are virtually separated, giving in the intervening space a large furnace for the complete combustion of the hydro-carbons before the heating surface is reached.

Operating Results

"L" type stokers are operated at from 200 to 300 per cent rating on coking and caking coals of the East. Efficiencies of 72 to 80 per cent are being obtained. The attendant labor is very low, one man operating up to 12,000 horse power continuously.

Ash and Clinker Removal

Stokers of the "K" or "L" type are particularly adaptable to high ash coals or to coals whose ash fuses at a low temperature (clinkering coals); also to the low ash coking coals of the East. Green Chain Grate and "L" type stokers remove the ash continuously from the furnace, so that there is no clinker formation requiring any dumping periods. Coals containing 30 to 35 per cent ash are being burned regularly and continuously on these stokers with low attendant labor and with no clinker trouble. During the past year, although we had over one and one-half million horse power in service, we did not have any shut-downs due to clinker trouble in any of the plants served by our stokers.

Single units up to 15 feet wide are built so that single stokers can be adapted to serve boilers up to 1000 rated horse power. No steam jets are used along the sides or bridgewall to prevent clinker adhesion, and the steam to drive even the largest unit is less than 30 pounds per hour. All efficiencies and capacities obtained are therefore net results, not subject to any deductions for auxiliaries, clinker prevention and clinker removal.

Sanford Riley Stoker Company

Since the last report of the Prime Movers Committee of the N.E.L.A. the Sanford Riley Stoker Company has concentrated much effort in the further development of its distinctive feature, the reciprocating retort sides, so that the motion of the furnace parts would extend the entire length of the furnace.

In the early developments of the stoker, each line of grates was movable up to the ash plates. The advantages of these reciprocating retort sides proved so pronounced in eliminating side wall clinkers and slicing up the fuel bed that it was conceded that if this desirable motion

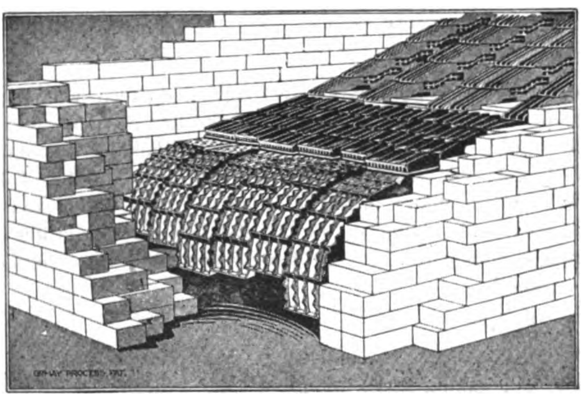

FIG. 21—SANFORD RILEY ROCKER DUMP

were extended, clinker troubles at the lower end of the furnace would be greatly mitigated.

The problem, therefore, was to eliminate this trouble as far as possible by developing a device which could be attached to the lower end of the retort units so as to move in unison with them. A modification was made in the overfeed grates which enabled the application of what is known today as the "Rocker Dump," illustrated in Fig. 21.. Its principle of operation is practically a continuation of the retort side motion intensified near the bridgewall.

The Rocker Dump resembles and its motion may be likened to that of an inverted rocker. The reciprocating retort sides give the upper ends of the rocker plates a horizontal motion, while the lower ends move in a perpendicular plane parallel to the face of the bridgewall. The enlarged detail drawings shown in Figs. 22 and 23 illustrate the

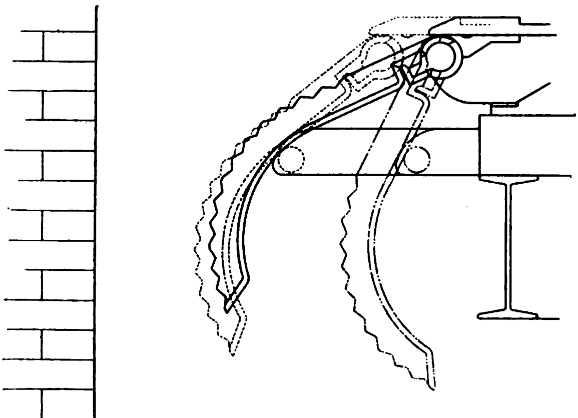

Fig. 22—Sanford Riley Company Rocker Dump Partly Open

path of these plates when the dump is closed, half open, and open.

It should be noted particularly from Fig. 23 how the forward and downward stroke of the rocker plates, over the rollers on the ends of the racks, automatically agitates, crushes and discharges the ash. On the return stroke the plates rise so as to break up the formation of clinkers.

The peculiar shape of the rocker plates has a distinctive advantage, as the constant agitation of the plates in different directions keeps the refuse open and porous, permitting the air to mingle intimately with and thoroughly burn out any combustible in the refuse before reaching the discharge opening. Owing to its simplicity it is not liable to the misuse and abuse that sometimes befalls the ash disposal mechanism when placed in careless hands.

The motion given to the rocker plates is positive and continuous so

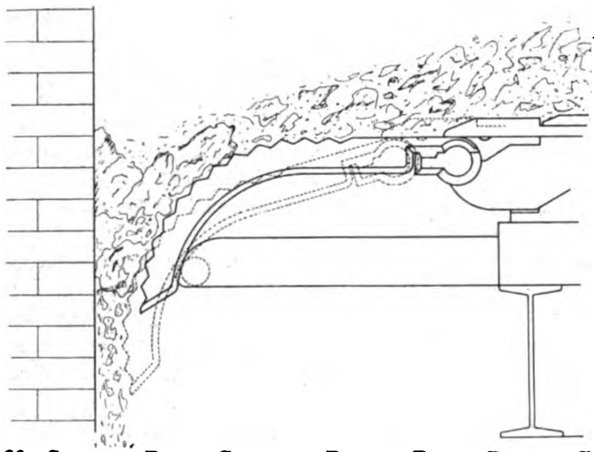

FIG. 23—SANFORD RILEY COMPANY ROCKER DUMP PARTLY CLOSED

that soft clinkers or slag adhesions cannot affect its operation. The motion of the rocker plates may be varied at will and is regulated to suit the percentage and clinkering qualities of the ash. The rocker plates give maximum agitation at the vital point—when the dump is nearly closed, as shown in Fig. 23, and when nearly open, as in Fig. 22, it gives maximum crushing effect so as to aid the operator when in emergency he wishes to make a quick disposal of ash and refuse. However, this is seldom, if ever, required.

During the last year a large number of stokers equipped with the new Rocker Dump have been put into operation. In large plants a material saving in fuel and labor was made possible, since the boilers could be operated continuously at high capacity without periodic losses due to cleaning.

Perhaps one of the greatest needs for the Rocker Dump has been in sections burning coals of low heat content and high in ash. The continuous discharge of ash at the rate formed did not allow the refuse to accumulate and cut down the fuel burning capacity of the stoker.

The two-speed gear box shown in Fig. 24 gives an adjustable fuel supply. With larger units the fire can be levelled, thinned or thickened as required.

When a number of stokers or gear boxes are driven by a single prime mover, any stoker or the retorts on any gear box can be operated practically independently of all other stokers or gear boxes. This effects a saving in fuel, since there is no necessity for carrying over coke when trying to divide the load equally among a number of boilers or when building up thin sections in a wide furnace.

With the stokers driven by an ordinary engine or motor, double the range of speed is obtained.

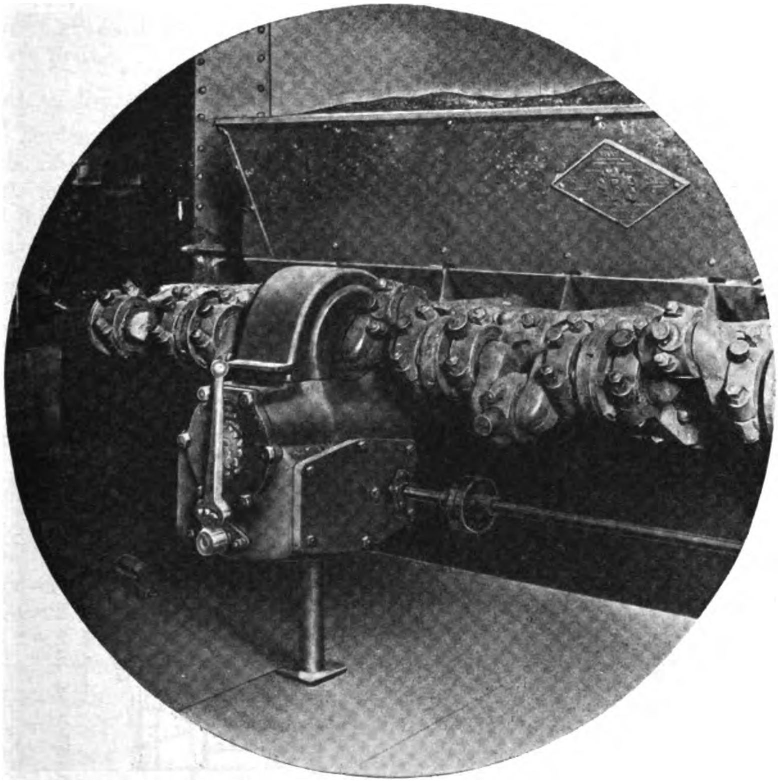

FIG. 24—SANFORD RILEY TWO SPEED GEAR BOX

The installation of the two-speed gear box gives a very flexible fuel control and makes the slip ring induction motor more suitable for stoker drive. A 2 to 1 reduction in speed is all that can be obtained electrically, but with this new device an overall range of 4 to 1 is obtained. A single throw of the shifter lever from left to right cuts the coal supply in half. This is done without a change in the speed of the motor. Stokers equipped with the two-speed gear box have but one chain connection per stoker. With large units this saves a great deal of mechanism underneath the stoker.

At the Camden plant of the Public Service Electric Company of New Jersey it was found that by using the two-speed gear box the stokers could be set much lower. In fact, the bottom of the box can, if necessary, be set directly on the floor. This is an economical advantage with low set boilers, since it enables the stoker to be set low, and gives maximum combustion space for the gases.

The use of this additional regulating feature does not interfere in

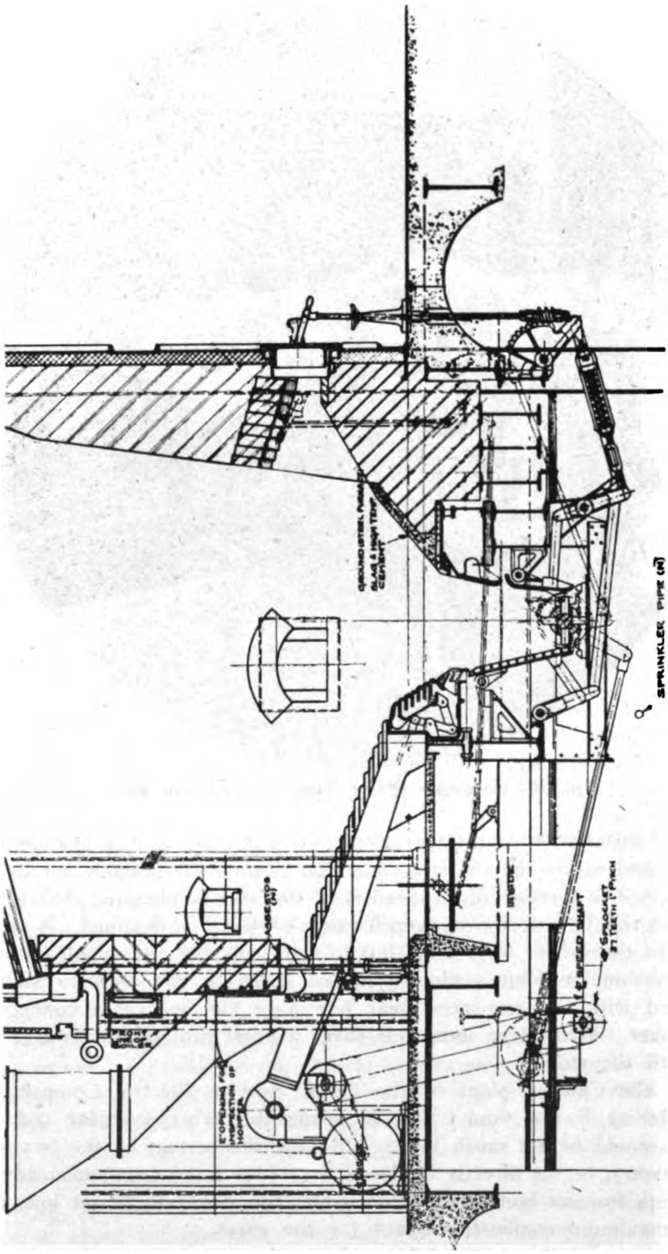

FIG. 25—WESTINGHOUSE SINGLE ROLL CLINKER GRINDER

any way with the continued use of any automatic regulating device; in fact, it allows a more intelligent use of any automatic regulator on the stoker drive.

Westinghouse Electric and Manufacturing Company

During the past year the stoker has been burning successfully a wide variety of fuel, from the eastern bituminous and semi-bituminous coals to the middle western coals and lignites. These plants are drawing their coal from the Pennsylvania, West Virginia, Western Kentucky, Illinois, Alabama, Iowa and South Colorado fields.

Power Dump

Three types of power dumps have been developed—steam, hydraulic and electric. Tests on these dumps have shown that they can be operated in from 45 seconds to 1½ minutes, depending upon the type installed and the character of fuel, with little or no drop in capacity and a minimum disturbance of furnace condition. The combustible in the ash varies between 10 and 15 per cent.

Clinker Grinders

For high ratings over long periods, a continuous method of ash disposal becomes imperative. Both single and double roll types have been developed. The single type, shown in Fig. 25, has been applied to stokers, 5 retorts wide, and 13 retorts wide. The double type shown in Fig. 26 has been applied in certain large installations. Both types have proved quite satisfactory.

Front Wall Air Boxes. Corrugated fronts were tried but discarded. The original design, which seems best, has been increased in weight, giving longer life. In one case a detachable nose, easily replaceable, has been installed. In addition to the front wall air boxes, some settings have been designed with chambers in them having outlets just over the fire in both the side and front walls, from which increased life is expected.

Top Tuyeres. The top tuyeres have been increased in height and weight. This has overcome trouble due to smoking coal hoppers, and by changing the shape of the coal bed at the front wall the reverberatory effect of the flame has been done away with, thus decreasing the erosion of the front wall.

Air Distribution. The general method of air distribution remains the same. To give more positive control, sliding gates are used instead of the butterfly gates.

Burning Mixed Coals. A test was made on burning different mixtures of bituminous and No. 3 buckwheat, varying from 100 per cent to 50 per cent of soft coal; the stoker handled these different mixtures very successfully, showing efficiencies varying from 72.5 to 64 per cent at ratings varying from 163 to 238 per cent of rating.

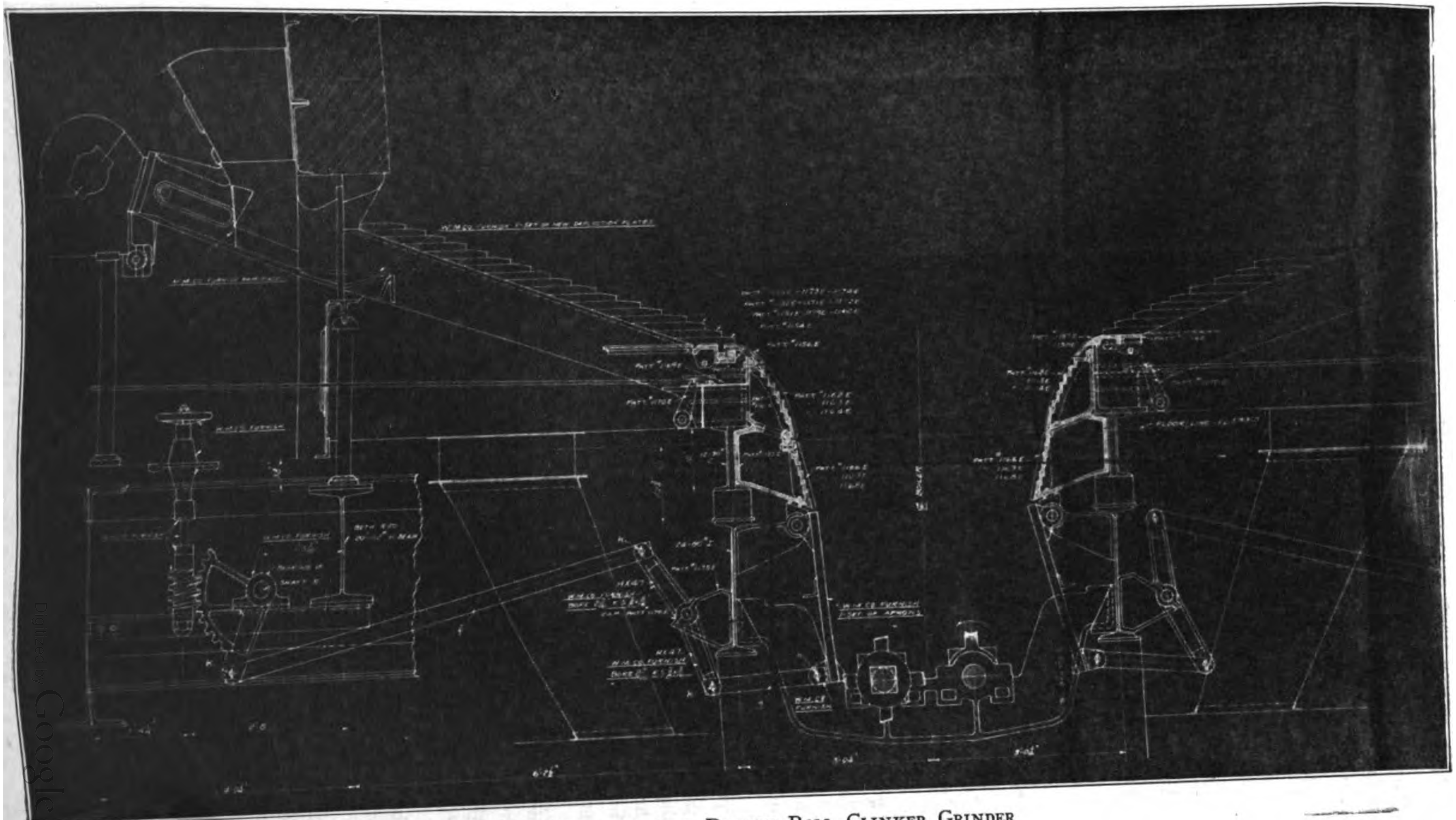

Fig. 26—Westinghouse Double Roll Clinker Grinder

Coke Breeze. Tests are being made on an actual installation to determine what modification may be necessary to adapt the stoker to burning coke breeze, and the results of this work should be available within a short time.

ECONOMIZERS

The last extensive discussion of economizers in a Prime Movers Committee Report was contained in the 1915 report in which detailed data were given concerning the practice of the Commonwealth Edison Company of Chicago. Since that time some progress in economizer practice has been made in the United States and abroad; types have been developed for pressures of 300 pounds or higher, using extra heavy cast iron or "semi-steel" tubes, and improved designs for headers, joints and other details. A few high pressure steel economizers are in use in this country, and a large number abroad. With the higher costs of fuel, economizers will doubtless come into much wider use.

Economizers can be conveniently classified, from three different points of view, into low or moderate pressure and high pressure, external and internal (in the boiler setting), and cast iron and steel. An early common type was the low pressure cast iron tube economizer set in its own housing. The ordinary arrangement was for one economizer to serve a group of boilers, and while this arrangement is now retained for groups of relatively small boiler units, more recent practice, especially with the larger boilers, is to use an economizer with each boiler. For low pressure economizers cast iron is the accepted material, as this is not as subject to corrosion as steel and is amply strong for the service. In the high pressure type of economizer there is a choice between cast iron and steel, the former being safer from corrosion and the latter from rupture. A number of plants have been designed with a combination of low pressure and high pressure economizers, the former being of cast iron and external, and the latter in general being of wrought steel and being placed inside the main boiler setting.

With a straight high pressure economizer the boiler feed pump takes the water from the heater and forces it through the economizer into the boiler. An alternative arrangement, using a moderate pressure economizer, is for one pump or one group

of stages of a multi-stage pump to handle the water from the feed water heater through the economizer, with a second pump or the second group of stages of a pump to force it into the boiler. Similarly for a combined installation of low and high pressure economizers there can be various arrangements of feed pumps, such as (a) one pump handling the water from feed water heater into a low pressure economizer and a second pump forcing it through the high pressure economizer into the boiler; (b) a pump divided into two groups of stages as outlined or an alternative arrangement for the moderate pressure economizer only; (c) two pumps on one shaft.

For internal cleaning the use of rotary machines is common. For external cleaning of tubes some operators use scrapers, and some soot blowers. In general, scrapers are fairly successful, although a number of minor operating troubles are experienced. Soot blowers have the advantage that they do not require the openings into the economizer setting, permitting undesirable infiltration of air. Soot blowers are sometimes criticized for the introduction of moisture, which under some circumstances would tend to increase tube corrosion; on the other hand, some operating companies have been using soot blowers for a number of years, without experiencing any troublesome corrosion.

So far as the data shows, cast iron tubes are not subject to serious internal corrosion. The pitting usually experienced with cast iron tubes is on the outside and is due to moisture condensed from the flue gases, especially when the coal carries a large amount of sulphur, and sulphurous acid is formed. This condition often necessitates heating the feed water in the heater to a temperature above the most economical point for economizer absorption. The practice with regard to temperature of feed water going into the economizer varies from 100 to 200 deg. fahr., depending upon local conditions such as character of fuel and amount of exhaust steam.

Wrought steel economizers are sometimes used for the higher pressures, but considerable trouble from internal corrosion has been reported from experience in England and on the Continent, and from recent experience in this country. According to latest information, this is largely due to entrained air or oxygen in the water; although most of this has been

removed from the condensate as it comes from the condenser, by means of the air pump, opportunity is offered in the heater and elsewhere for the entrainment of oxygen. Several methods to eliminate this oxygen have been tried, among which are the following: (a) Heating the water, before it enters the steel economizer, to a temperature often higher than desirable from the point of view of economy. (b) Removal of the oxygen by passing the water, after it comes from the heater and at some stage in its journey to the boiler, through a tank kept under a partial vacuum; this introduces a somewhat troublesome complication. (c) The use of iron filings or some similar material for taking the oxygen from the water by means of oxidation; according to the technical press, this has been tried to a considerable extent in Europe with some success. It is too soon to make any definite statement with regard to the success or failure of these various methods.

A brief questionnaire was sent out to a number of insurance companies, especially with a view of obtaining advice as to probable future pressure limitations in cast iron economizers. The insurance companies replied through the manager of the Steam Boiler and Fly-wheel Service Bureau, after a meeting of a committee of their engineers. The brief reply is quoted below, the first section having to do with pressure limitations, the second covering any modification of economizer material (*e.g.*, "semi-steel"), and the third in reply to a request for general comments on insurance requirements regarding cast iron tubes or fittings for steam plants when carrying high water pressures.

(*a*) We consider it impractical to specify any pressure limitation. A temperature limit rather than a pressure limit should be applied in determining the safe operation of cast iron economizers as now generally manufactured.

(*b*) As regards modified forms of cast iron economizer tubes, as for example so-called semi-steel tubes, we would say that this material, so far as our experience goes, is nothing more than a high grade of cast iron, and we do not believe that any considerable distinction should be made between it and cast iron.

(*c*) While this question is not entirely clear, yet we recognize the American standard for fittings.

It may be inferred from this ruling that the insurance com-

panies do not desire to take any arbitrary stand with regard to pressure limitations in cast iron economizers, feeling that rational engineering design giving ample factors of safety and the results of experience should be the guides. It is believed that the engineers for the operating companies will be just as conservative with respect to pressure limitation as the insurance companies.

It is impossible to make any general statement concerning the advisability of installing economizers in connection with a boiler plant; each case has to be considered by itself, taking into account all factors, such as cost of fuel, cost of economizers, and especially the load factor under which the boiler plant is to operate. The theoretical saving may range up to ten per cent or even higher, but the net saving on the other hand, after making due allowance for fixed and operating charges on the economizer installation, may be found negative instead of positive.

As commonly computed, the saving to be effected by the economizer is based on boiler plant figures only, and in order accurately to compare the operation of an economizer boiler plant with one not so equipped, the computed economy should include consideration of prime movers and auxiliary equipment as well.

In the operation of economizers it has been accepted almost without argument that to obtain maximum benefit the water should enter the economizer at the lowest possible temperature, the minimum limit being set by external corrosion difficulties. To obtain this low temperature, electric drive is in general adopted for most of the station auxiliaries, and this introduces factors which to some extent offset the advantage gained from feeding the lower temperature water to the economizer. With steam driven auxiliaries, assuming that the exhaust is all used in the feed water heater, one kilowatt-hour of energy supplied to the auxiliaries costs 5,000 to 6,000 B.t.u. With auxiliaries driven electrically, the cost is commonly 25,000 to 30,000 B.t.u., and hence for each kilowatt-hour of auxiliary steam energy displaced by electric drive, in order to keep the feed water temperature at the entrance to the economizer down to the minimum, about 20,000 B.t.u. are sacrificed. In order, therefore, to realize a net saving on the station operation, the increased effi-

ciency of the boiler economizer plant, due to the reduction in feed water temperature, must be more than sufficient to offset this sacrifice.

A computation for certain assumed conditions showed an improvement of economy of about 0.5 per cent by using 125 deg. ingoing water as against 200 deg. including consideration of auxiliary drive; the saving for the same assumptions based on boiler plant operation only was three times as great.

The answers to a questionnaire sent to member companies operating economizers are summarized in Table II.

As regards difficulties encountered in operating economizers, it is true that a considerable number of service troubles (other than corrosion) and a few explosions have been experienced with cast iron economizers; on the other hand a number of plants using high pressure types report no serious difficulties. Some operators question the soundness of present cast iron economizer design for pressures over 200 pounds, preferring to limit the service to moderate pressures, but others believe that the designs can be made reasonably successful up to 300 pounds, and perhaps higher.

This Committee is not prepared to make any definite recommendations concerning the type and arrangement of economizers to be used for the higher pressures. A single high pressure economizer connected in series with the boiler is a simple and a desirable scheme, if a safe material can be found and if corrosion troubles with this material can be prevented. If these conditions cannot be fulfilled, it may be found necessary to divide economizers into two distinct stages, with the attendant expense and complication. For large central stations and for pressures up to 250 or 300 pounds, practice seems to be tending toward the use of single high pressure cast iron tube economizers working in series with the boilers, one economizer being connected to each boiler. Probably for higher pressures, and perhaps for pressures more common today, arrangements will be worked out using wrought steel economizers—always providing that the corrosion troubles can be taken care of in a reasonably satisfactory manner.

The Committee is in receipt of statements from the following manufacturers covering developments during the past year:

TABLE II

SUMMARIZED STATEMENT OF ECONOMIZER PRACTICE

Company Item	A	B	C	D
Type of economizer	External, 340 lb. pressure, semi-steel tubes	External, high pressure, cast iron	External, high pressure, wrought steel tubes	External, 340 lb. pressure, cast iron
Boilers	12,320 sq ft, 300 lb pressure	13,730 sq ft, 220 lb	15,000 sq ft, 250 lb.	11,400 sq ft, 275 lb.
Ratio economizer surface to boiler surface......	0.63	0.56	0.52	0.83
Temperatures ...	Water 170 to 235, gases 500 at 200% rating	Water 140 to 235, gases 500 to 300, 150% rating	....	Water 208 to 308, gases 600 to 387
Net saving by use of economizer	6%	8%	....	....
Method of cleaning	Scrapers	Soot blowers	Soot blowers	Scrapers
Cost of cleaning	....	5c per sq ft per yr	....	....
Cost of maintenance	....	1c per sq ft per yr	....	....
Type of fan drive	Variable speed d-c motor	Constant speed motor, silent chain drive, natural draft used up to 175% boiler rating	Motor driven fan for each unit	Slip ring induction motors with 15% range in speed
Pumping arrangement	Two sets pumps, one between heater and economizer, one between economizer and boiler	Boiler feed pumps through economizer to boiler	Boiler feed pumps through economizer to boiler	Boiler feed pumps through economizer to boiler
Corrosion	New installation	No trouble	....	No trouble
Gas by-pass	Yes; no occasion as yet to use	Prefer by-pass	No, price of by-pass and room it takes amount to more than benefit gained	Yes, provided investment cost is not too high
Choice of types of economizer	Individual economizers preferred	Depends largely on size of boiler and plant layout; where practicable believe in unit system	Individual economizers preferred except in small plants with small boilers; where two or more large economizers may be installed with breeching so arranged that either can be cut out for cleaning	Individual economizers preferred

E	F	G	H	I
External, high pressure, cast iron	External, 300 lb pressure, cast iron tubes	External, high pressure, cast iron	External, high pressure, originally cast iron tubes later replaced with semi-steel	External, high pressure cast iron
8.750 sq ft, 220 lb	6,860 sq, ft, 230 lb	13,750 sq ft, 244 lb	12.260 sq ft, 215 lb	12,620 sq ft, 240 lb
0.41	0.45	0.56	0.69	0.65
....	Water 116 to 256, gases 550 to 320 160% rating. Water 107 to 270, gases 615 to 355 220% rating	....	Water 140 to 260, gases 600 to 325, 200% rating	Water 100 to 240, gases 620 to 330, 255% rating
Estimate 8 to 10%	....	....	1.6%	....
Scrapers	Scrapers	Scrapers; reasonably successful	Scrapers; only fairly successful	Scrapers; could be improved
....	....	....	....	....
3c per sq ft per yr	....	Annual maintenance guaranteed 1%	Average 16½c per sq ft, period of 5 yrs	....
No fans, natural draft	Motor driven fan, silent chain drive	Variable speed a-c motor, with water rheostat secondary control	Motor driven induced draft fan	Motor driven induced draft fan
Boiler feed pumps straight through economizer to boiler	Boiler feed pumps through economizer to boiler	Boiler feed pumps through economizer to boiler	Boiler feed pumps	Through economizers to boilers
No trouble	No trouble	....	Considerable trouble with tubes pitting due to sulphurous deposit, especially on cold end of economizer	No pitting yet
Not with individual economizers for boilers	No	Yes	Yes	Yes
Individual economizers preferred	Thoroughly believe in unit system	Individual economizers for large boilers; small boilers one economizer for a battery	Individual economizers preferred	Individual economizers preferred

Babcock and Wilcox Company

This company is interested in the development of a wrought steel economizer, built either integral with the boiler or separate; the latter might be enclosed in the boiler setting or in a neighboring separate housing. The manufacturer is actively at work on the problems arising with this type of economizer, and it is stated that the work is bringing promising results as to the elimination of corrosion in wrought iron or steel economizers. The work being incomplete, no statement can be given out.

Green Fuel Economizer Company

Recent Developments

Fuel economizers have within the past few years been re-designed throughout to suit them for high pressures. Even greater factors of safety than existed in the low pressure type have been introduced and maintained.

Individual Economizers

The unit arrangement of economizers, which has been introduced on account of the large size of modern boilers, is applicable to boiler units over 5000 sq. ft. when they are operated at high ratings; for lesser outputs there is no advantage in individual economizers. The unit arrangement makes a simpler layout, eliminating considerable flue work, air leakage and radiation losses, and the economizers themselves can be made shorter and more efficient. It is also an advantage to be able to inspect and clean the economizer at the time its boiler is down for cleaning.

Moderate and High Pressure Types

Hundreds of economizer installations are working in this country and abroad, giving excellent service under pressures of from 200 to 250 lb. Development of economizers for boiler pressures from 300 to 350 lb. has also been satisfactorily carried out, using cast iron tubes; it is believed that wrought iron and steel tubes as at present manufactured are not suitable for economizer practice; with such tubes it is necessary to carry the incoming water above 200 deg. fahr.

Pressure Limitations

It is believed that it is conservative to use cast iron economizers up to 350 lb. pressure, and that the increased pressure on the economizer does not make the machine any more dangerous. Designs are now being worked upon by which the holding power of the tubes in the header will be largely increased, and the action of these joints made positive. Recent tests on economizer tubes have shown pressures up to 4000 lb. per sq. in. No explosion of a cast iron economizer has taken place, due to the material from which it was made.

Specifications for Material

Iron used in the construction of economizers should be hard, close grained, and of high tensile strength. A small percentage of steel should be added and great care taken that this is evenly distributed; not over 10 per cent of steel should be used under any circumstances, as this would result in more rapid deterioration of tubes and headers.

Pitting

Cast iron will not pit seriously unless the economizer is fed with water below 90 deg. fahr.; the temperature would preferably be at least 100 deg. Cast iron economizers have been known to serve for over fifty years without serious deterioration.

Heat Transfer Rate

Heat transfer varies from 2.5 to as high as 7 B.t.u. per sq. ft. per hr. per deg. fahr. difference of temperature. The general introduction of induced draft has permitted engineers to use much higher velocities through economizers than was formerly possible, with the result of doubling the unit heat transfer.

Fuel Saving

For an assumed case, with boilers operating at 200 per cent rating, entering water at 125 deg. fahr., outgoing water at 227, and entering gas 575 deg., the equivalent fuel saving by the use of an economizer would be 9.6 per cent; deducting 2½ per cent of the steam generated for operating the induced draft fan and the scrapers, the net improvement by the use of the economizer would be 7.9 per cent. The 2½ per cent allowance for the fan and scrapers could be reduced if an engine or turbine drive for the fan exhausted into the feed water heater.

Cleaning

Although steam soot blowers have been used for economizer cleaning, in order to avoid certain mechanical difficulties sometimes experienced with ordinary scraper mechanism, and to avoid air infiltration through the chain holes, soot blowers are believed to introduce drawbacks which more than offset any advantage. Moisture is allowed to enter the economizer chamber, increasing corrosion and shortening the life. It is felt that most scraper trouble is due to the intermittent operation often practiced, and that if scrapers are kept in continuous operation and given ordinary attention, there should be little trouble with them.

Maintenance

Based on records kept over a period of ten years covering three million dollars worth of economizers, the average annual cost of economizer maintenance for the first ten years is believed to be well under one-half of one per cent of the investment.

Tech.

Pumping Arrangements

A centrifugal pump is preferred to a plunger pump. A water relief valve should always be installed on the pipe line between the feed pump and the economizer, and the pump and piping arrangement should be such that there is no question about a definite amount of water passing through each economizer.

B. F. Sturtevant Company

Recent Developments in Design

The outstanding improvement in design is the development of a "high pressure machine," using extra thick semi-steel tubes with special joints; a number of sections have failed under test at pressures from 2200 to 2400 lb. per sq. in. Water circulation has been improved superseding "natural" by "positive" circulation, arranging the economizer in three or more passes, the commonest being five.

Individual Economizers

The big change in practice is the development of the unit system; with the advent of boilers from 10,000 sq. ft. up, run at peak ratings from 250 to 350 per cent of normal, a single boiler puts out as much steam as the total of an old-fashioned boiler room. As there is a limit to the size of the economizer, the application of one economizer to one boiler comes about as a natural development. The chief advantage is that each boiler economizer unit is practically independent and that the plant as a whole is more flexible; there is usually also a considerable saving in flue work, especially when a by-pass is not used.

Moderate and High Pressure Types

For plants in which the pressure *in the economizer* is below 250 lb.; a standard type "M" economizer is recommended. When pressures range from 250 to 350 lb., the extra heavy high pressure machine is indicated. During the past four years a considerable number of high pressure equipments have been installed, working under pressures from 250 to 350 lb., with no trouble from breakage or leakage in service.

Pressure Limitations

It is believed that 350 to 400 lb. may be considered the limit for pressures in cast iron (including semi-steel) economizers. The ultimate strength figures for standard and high pressure economizers are as given in the following table, in pounds per square inch internal pressure; the figures given for the pipe joints are from actual tests by sections, and the other items are figured by formula.

	Standard Pressure	High Pressure
Top header	4,650	7,750
Bottom header	5,625	10,100
Pipe	4,920	8,160
Bends	6,240	9,850
Manifolds	3,765	7,280
Wall boxes	5,500	9,000
Pipe joints	1,400-1,800	2,200-2,900

It is seen that for pressures up to 350 lb. the factor of safety is apparently large; every precaution is taken to discover such defects as blasts, sand holes, cold spots, etc., by mechanical and hydrostatic testing.

Specifications for Material

The specifications for economizer iron call for high tensile strength, close grain, low sulphur content, and minimum amount of silicon compatible with the strength required. The iron should be tough, not brittle, and with a maximum of strength. Cast iron should have a tensile strength of at least 25,000 lb. per sq. in., and a sulphur content of not more than 0.1 per cent; semi-steel a tensile strength of not less than 35,000 lb., with a sulphur content of not more than 0.1 per cent. As large a proportion of steel is used as is possible, without rendering the iron too hard to machine, making it brittle, or making it subject to corrosion.

Pitting

A careful study of economizer corrosion, including chemical and physical analyses, indicates that the incoming water should be at a temperature of 120 deg. fahr. or higher, in order to prevent condensation from flue gases during steady operation. For the first 15 to 60 minutes, however, after putting an economizer into service, the water in the economizer is cold, and injurious moisture and acid deposit often take place. This could be avoided by heating the feed water during this initial period, by using either live steam or hot water from the boiler.

A suggestion for future development is the use of nickel-steel for economizer parts, chemical tests showing this to be more resistant to action by sulphuric acid than cold rolled steel, cast iron or semi-steel. The last-named is next to the nickel-steel in non-resistance to sulphuric acid, but wastes away several times as fast. It is difficult, if not impossible, to prevent corrosion, using for tubes the grades of steel and wrought iron now available. In no case should water enter wrought iron economizer tubes at a temperature below 212 deg. fahr.

Ratio Economizer to Boiler Surface

The ratio between economizer and boiler heating surface of course depends upon operating conditions; the usual practice varies from 0.45 to 0.75.

Water and Gas Temperatures

The two factors which should govern temperatures of incoming and outgoing water are the temperature of the steam in the boiler and the commercial consideration of return on the investment. In practice, the water temperature should not be allowed to rise higher than within 40 to 50 deg. fahr. of the steam temperature; in some cases water has risen to within 25 deg., but this should never occur where there is likely to be sudden or large drop in steam pressure, or where there is a variable ratio of water and gas weights.

A heat rise curve, plotted to coordinates of the length of the econo-

mizer and the temperature rise, takes the form of a rectangular hyperbola and approaches a straight line; in other words, as more sections are added, the rise per section becomes less. Beyond a certain number of sections, therefore, the commercial return does not warrant putting in further sections.

In steel mills entering gases have been as high as 1200 to 1500 deg. fahr.; in the average power plant the temperature of incoming gas is always within practical limits. The temperature of outgoing gas is largely controlled by the water factors mentioned above, but in practice the gas should not be reduced below 300 deg. fahr. for natural draft, this being controlled by the height and capacity of the stack; when mechanical draft is used the outgoing gas should not fall below the temperature of the incoming water plus 100 deg.

Heat Transfer Rate

For all practical purposes, the heat transmission rate varies directly as the velocity and density of the gas; for purposes of computation therefore the unit "lb. gas per hr. per sq. ft. of free area" is used. In economizer practice the transmission rate varies from 1.5 B.t.u. per sq. ft. per hr. per deg. fahr. difference of temperature with stagnant gas, up to 6 B.t.u. with 5000 lb. gas per hr. per sq. ft. of free area. In figuring actual economizer problems, account has to be taken of radiation, convection and infiltration.

Cleaning

For cleaning internal surfaces of economizers rotary tube cleaners should be used. The time required for cleaning an economizer 32 to 40 sections long and 12 pipes wide is approximately one week, using four men.

Maintenance

Based on experience over a number of years, the annual economizer maintenance is figured at 3 per cent of the price; the usual practice is to figure 7 per cent for depreciation, 1.5 per cent for repairs, and 1 per cent for insurance, besides the 3 per cent maintenance.

Pumping Arrangements

In the case of a single economizer, in one stage, the feed piping is arranged the same as without economizer; the connection to economizer inlet is taken out of the line and the connection from economizer outlet brought back into the line, with suitable valves to permit running water either through or past the economizer. There should be a check valve on economizer inlet and a relief valve on pump outlet. Centrifugal pumps are preferable, and if reciprocating pumps are used there should be provision for eliminating shock. Where two economizers are arranged in parallel as regards water path, each should be connected separately to the boiler which it serves or else all the water should pass through both economizers. The feed water should be regulated by the speed of pumps,

TABLE III

Important Economizer Installations 1915-1918

Company	Sq. ft heating surface per boiler	Percentage of "normal" rating	Sq. ft of economizer heating surface	Ratio of economizer to boiler heating surface	Lb of gas per hour	Initial temperature of gas, deg Fahr.	Lb water per hour	Initial temperature of water	Rise in feed water temperature deg Fahr.	Steam pressure lb per sq in, gauge
A	12,320	100 to 300%	7,728	0.63	68,000 to 240,000	450 to 700	33,000 to 100,000	130 —	85 to 160	—
B	12,780	100 to 300%	7,728	0.60	76,000 to 263,000	475 to 665	42,000 to 122,000	120— 150	81 to 119	—
C	10,000	100 to 300%	5,918	0.59	55,000 to 186,000	450 to 625	30,000 to 91,000	120— 210	59 to 120	—
D	12,000	—	9,435	—	—	—	—	—	—	325
E	8,460	150 to 312%	6,440	0.76	95,000 to 200,000	510 to 700	44,000 to 75,000	160	94 to 165	—
F	14,000	—	8,240	—	—	—	—	—	—	200
G	12,620	300%	9,274	0.74	252,000	600 to 650	100,000	100	145 to 165	—
H	12,500	—	8,518	—	—	—	—	—	—	250
I	6,860	160 to 260%	4,220	0.61	93,000 to 143,000	550 to 630	33,000 to 46,500	140	112 to 130	—
J	4,440	—	6,300	—	—	—	—	—	—	250
K	12,620	300%	9,274	0.74	270,000	600 to 650	100,000	100	145 to 165	—
L	12,220	215%	8,500	0.70	240,000	550 to 600	80,000	100	138 to 173	—
M	12,200	300%	7,341	0.60	270,000	550 to 600	80,000	100— 120	125 to 156	—
N	4,400	—	4,020	—	—	—	—	—	—	235
O	11,160	150 to 200%	6,854	0.62	175,000 max.	450 to 600	47,500 to 63,000	100 —	115 to 125	—
P	13,700	—	5,504	—	—	—	—	—	—	250
Q	7,500	—	4,000	—	—	—	—	—	—	275
R	7,900	—	4,080	—	—	—	—	—	—	300

or by a feed valve between pump and economizer, and not by a feed valve between economizer and boiler.

In connection with the foregoing statements from manufacturers, a list of important economizer installations made during the past three years will be found in Table III.

Power Station Auxiliaries

Previous reports of this Committee have pointed out new developments of power station auxiliaries from the standpoint of increased reliability and economy, and the necessity for careful consideration of this question in connection with design and operation, if maximum overall economies are to be obtained. The increasing price of fuel and the determined conservation drive during the war have been responsible for considerable improvement in the application of basic underlying principles. Engineering study of the subject will show that after due consideration is given to required reliability and reserve capacity, the problem resolves itself into one of maintaining the steam balance on varying load with the maximum possible auxiliary brake horse power from exhaust steam discharging to the heater. The method of auxiliary drive is of course a compromise between this condition, the question of reliability and the carrying charges on the first cost.

It has been pointed out that in a modern type of steam auxiliary using 30 pounds of steam per brake horse power hour the cost per b.h.p. of auxiliary power will be about 4500 B.t.u., providing all steam is absorbed by the heater; also that the excess exhaust steam which cannot be absorbed will cost 8 to 10 times this amount; also that electric auxiliary power from a modern prime mover will cost 22,000 to 25,000 B.t.u. per kw-hr. A careful analysis of a given operating condition with these figures in mind will show that the smallest thermal cost for auxiliary power is expended when steam auxiliaries having a minimum consumption per brake horse power hour are used up to the limit of feed water absorption capacity, and the balance of auxiliary power required is taken from the main bus bars. The installation of economizers will reduce the desirable limit of absorption by feed water on account of the greater savings effected by

economizers when feed water is supplied to them at lower temperatures than 212 deg. fahr.

The above fundamental principles have been applied by member companies generally according to the following schemes:

Dual System

Part steam and part electric with duplicate circulating water equipment or pumps equipped with induction motor drive on one end and steam turbine with variable speed governor on opposite end to control proportion of power by steam.

Straight Electric Drive

From main unit, bleeding intermediate stages of main prime mover for steam to heat feed water.

Straight Steam Drive

Using all steam possible to heat feed water, balance being fed to low pressure stages of main prime mover.

Straight Electric Drive with House Turbines

As much of the auxiliary load as possible is carried on comparatively large size turbine exhausting to condenser heater, balance on main prime mover.

Comparisons of practical operation under these methods are not fully available, but a survey of a number of typical installations shows that the dual system is more prevalent and gives the desired result where the load factor is reasonably good. Duplication of boiler feed pumps, air pumps or fans, part steam and part electric, are also used to control the steam balance under this scheme. House turbines show some additional savings over other schemes under some conditions, due to lower auxiliary water rate and the possibility of operating house turbines under a vacuum at light loads.

The replies to a questionnaire sent out to member companies for information as to station auxiliary apparatus brought out some points of general interest, and as the data should be valuable, particularly with reference to new designs, they have been abstracted as follows:

Exciter Drive

The improvements of the plant's excitation system from a standpoint of reliability have probably determined the method of exciter drive to a great extent. In general, exciters are not interchanged for controlling heat balance and are duplicated either in a form of bracketed, steam or motor driven exciters. The larger units are generally equipped with direct connected exciters, whereas the smaller plants employ motor drive for use in connection with voltage regulators. Steam driven exciters are very generally used for standby only.

Heaters

The type of heaters used in the various plants and the size still seem to be an open question. The majority of plants still prefer the open type on account of better elimination of entrained air and gas in the condensate and make-up. However, the elimination of oil seems to be the deciding factor in favor of closed heaters where used. Plants using jet condensers prefer the open type almost entirely. The question of proper storage ahead of the heater and between heater and boiler feed pumps is receiving considerably more attention than in the past, to eliminate possible losses of condensate and widely fluctuating feed water temperatures.

Fans

In a forced draft stoker installation where the unit air duct system is employed, a much larger aggregate fan installation must be made to insure the same reserve and overload capacity than is the case with the common duct system supplying a number of boilers and fed by a group of fans. With such an installation, furthermore, practically all the equipment is operating for a great part of the time at an uneconomical load.

On the other hand, the parallel operation of fans of the same design and construction is not always entirely successful. A decided improvement has recently been made in the efficiency of fans over a wide range of loads, and they are well adapted for either motor or steam drive, so that the selection of the type of drive is largely a matter of heat balance.

Boiler Feed Pumps

Boiler feed pumps are generally made turbine driven with

the differential pressure governor to maintain pre-determined relations between the water and steam pressure. Several of the member companies are using motor driven boiler feed pumps with entire success. Records of preliminary operation parallel with steam driven pumps tend to show that this condition is entirely satisfactory when pumps and control of proper types are used. One of the member companies uses a variable speed induction motor drive with the differential pressure controlled by an automatic pressure regulator. It is generally found necessary, or desirable, to maintain some automatic controlled differential pressure, particularly when used on a system equipped with automatic feed water regulators.

In summing up the points brought out in the above statements, it may be well to emphasize again the fallacy of arguments in the past, that the water rate of steam driven auxiliaries is not an item deserving much consideration. The results obtained by some of the more modern plants in the matter of auxiliary power cost will certainly show the importance of looking into the question of division of auxiliary drive, particularly in the smaller plants. Some small plant records have shown in their performance that under light load conditions the auxiliaries used almost as much steam as that delivered to the main unit, the excess either going to the condenser or to the atmosphere, either of which result is very wasteful. Investigations will sometimes indicate that only a slight revision in the method of operating in the older type of plants will accomplish surprising results at a nominal expense. For new work the matter of reliability of auxiliaries in connection with large prime mover units should be thoroughly emphasized. Member companies in most instances are using duplicate auxiliaries or cross-connecting auxiliary equipment. Member companies are specifying steam auxiliaries to operate at full capacity with a maximum drop of about 50 pounds in steam pressure. Electric auxiliaries are usually specified to operate on 10 per cent voltage variation in either direction. Member companies specified as much as 33⅓ per cent drop in voltage before pull-out occurs on drive motors. This is particularly true for exciter drive. It is suggested that some very important information can be obtained through an analysis of the auxiliary steam and of steam lost and unaccounted

for per kilowatt-hour in various stations using the different schemes of auxiliary power supply.

COAL STORAGE AND HANDLING

Storage

Writers on this subject show very little tendency to agree as to the cause of heating and deterioration of coal in storage, there being theories offered by eminent authorities supporting all possible and a good many impossible causes, this difference in opinion being due largely to the fact that most writers speak from the observation of local conditions both as to coal and climate.

There is considerably more agreement, however, on the results to be expected under certain conditions than there is in the theories offered as to their causes. Among the principles which are backed up by extensive experimental data and widely accepted by the authorities on the subject are:

(1) Coal does not deteriorate seriously unless it heats sufficiently to fire in some part of the pile.

(2) If the pile fires in one or more places, all of the coal in the immediate neighborhood of the fire is absolutely ruined as far as gas and coke making is concerned, though it can still be used as fuel for boilers.

Fires in coal piles are caused by sufficient air for combustion coming in contact with the coal at a point where it is too far from the surface for the heat to be dissipated by radiation or where the ventilation is insufficient for it to be carried away by air currents as rapidly as it is generated.

It is also conceded that fresh mined coal absorbs oxygen and consequently heats much more rapidly than coal which has been above ground for a considerable period, and that coal which has once been thoroughly heated and quenched will rarely fire again.

A consideration of the above causes suggested certain obvious remedies, among which the following have been successfully tried:

(1) The exclusion of air, which can be attained by:

(*a*) Storing under water which keeps the coal up to its original value for all purposes, for an indefinite length

of time. This method, while advantageously used in a number of cases, is open to a number of objections, among them being high first cost of plant, difficulty from ice in northern winters, difficulty in dewatering after removal from storage and trouble in handling wet coal in certain types of stoker. It has the very decided advantage, however, that the coal is always there when you want it and it is as good after five years' storage as when it was first mined. This advantage has been the deciding factor in causing the Navy to install under-water storage at Panama and other places in the tropics, where the atmospheric conditions would cause rapid deterioration of coal stored above ground.

(*b*) Storage in air tight bunkers. This method is mainly available on colliers where, if the hold is completely filled with either a slack coal or run-of-mine having a sufficient proportion of slack to fill up the spaces between the lumps, there will not be sufficient oxygen available to support combustion. It has been found of advantage in some cases to pump cold flue gases into the hold to reduce further the oxygen content.

(*c*) By storing a mixture of sizes so proportioned that the air spaces between the lumps are completely filled, and tamping successive layers of coal to further eliminate air spaces. This method, on account of the excessive amount of hand labor involved, is available only where small amounts of coal are stored and where hand methods of storing and reclaiming are used.

(2) Storage in piles small enough in size to allow the heat to be radiated as fast as it is formed. The size of pile necessary to accomplish this object varies greatly. There are some coals which will stand storing in piles 40 feet high containing over 50,000 tons to the pile for several years without serious heating, and there are others which cannot be stored over 4 feet high or in piles of over 1000 tons without catching fire in a few months. There is obviously, however, very little difference in the cost of coal-handling machinery for a pile of 40 feet high containing 40,000 tons and one 4 feet high containing 4000 tons. The low

pile coal consequently faces a very decided handicap in both first cost of plant and in cost of operation.

(3) The provision of sufficient ventilation to carry away the heat of combustion as rapidly as formed. This may be accomplished:

(*a*) By storing only lump coal which offers sufficient air passage through the pile to cool the coal. This system is practical only to a limited extent, as lump coal is used mainly for domestic purposes and is rarely stored in large quantities.

(*b*) By installing a system of ventilating ducts carrying to all parts of the pile sufficient air for removing the heat as formed. Numerous elaborate systems have been devised to accomplish this purpose and many of them tried out, but they have usually been abandoned after a year or two because it was found that the ventilating system cost more than the coal was worth.

With eastern coals the system of storage which is most widely used is to stack in high, large piles, and on the first sign of heating, dig out the hot spot, thoroughly drench it with water and stack it again in a new place, it having been found that coal once heated and quenched will rarely fire again. It is a prime requisite for the success of this system to have coal-handling equipment of ample capacity for rapidly transferring the coal at the first sign of heating. This system should not be confused with that of simply digging a hole down to the hot spot and trying to drench it with water, because this method does not give satisfactory results; nine times out of ten the water finds an easy channel to the ground and scarcely touches the hot coal on its way.

Volumes have been written on the proper time to store coal, some authorities advising storing in the winter when it is cold and consequently less likely to heat, others advising storage in August when the coal is dry. The power plant manager is usually confronted with the necessity of storing coal when he can get it and reclaiming it when he needs it: his storage consequently must be an all the year round proposition.

The storage of coal is a local problem. If it is stored to

take advantage of a cheaper price at certain seasons of the year, the difference in price is the limiting factor in storage costs. If storage is kept because it must be available at all times and deliveries are too uncertain to depend on, it becomes a question of method of storage and not one of storage or no storage. If several types of storage will give the same result, local conditions affect the type to be decided upon. In a number of cases underwater storage has been found practically ready made in the availability of abandoned quarries and clay pits; in others they would have to be created at great expense.

When it is decided that storage is necessary, the best procedure is to determine the quality of protection necessary for the coal you expect to use, if possible, from the experience of those who have stored coal from the same district, and then with the local conditions in view, provide in the cheapest way possible the protection which this experience has shown to be necessary.

It was the intention of your Committee, by means of a questionnaire, to show the comparative cost of various types of above-ground and under-water coal storage. Due, however, to the wide difference in accounting methods in the plants reporting, no definite conclusions can be drawn from the data so far received. It is the Committee's intention to follow up this matter, and it hopes, in the next report, to give definite information on this subject.

Handling

Methods of handling and reclaiming coal in some of the latest installations are covered by the following brief descriptions:

U. S. Government Explosives Plant "C"
Nitro, West Virginia

The two boiler houses are parallel to each other, with a space of approximately 300 feet between them. Each boiler house is 564 feet long by 49 feet 8 inches wide, and contains a single row of boilers. The space between the boiler houses is used for coal storage and coal-handling equipment. Midway between the boiler houses there is located a coal trestle with a capacity of approximately ten cars. This trestle consists of

wooden bents mounted on concrete footings and 24 in. I beam stringers. The coal is brought on to the trestle in standard gauge railroad cars and is dumped into the receiving pit, which extends the entire length of the trestle. Parallel to the trestle and on each side of it are tracks on which operate locomotive cranes for handling the coal. There are three locomotive cranes —two for regular service and one which is used as a spare. Each crane has a radius of 100 feet and is equipped with a 5 cubic yard bucket. Provision has been made so that the spare crane can operate at either side of the trestle. The coal storage is located between the crane tracks and the boiler houses. In normal operation, when coal is received and dumped below the trestle, it is picked up by the locomotive cranes and dropped into traveling crusher cars on top of the boiler houses. The crusher cars move along tracks on top of the boiler houses and distribute the coal evenly into the bunkers above the boilers. The cranes can also store the coal or make good any deficiency in coal supply by taking coal from the storage. The guaranteed capacity of

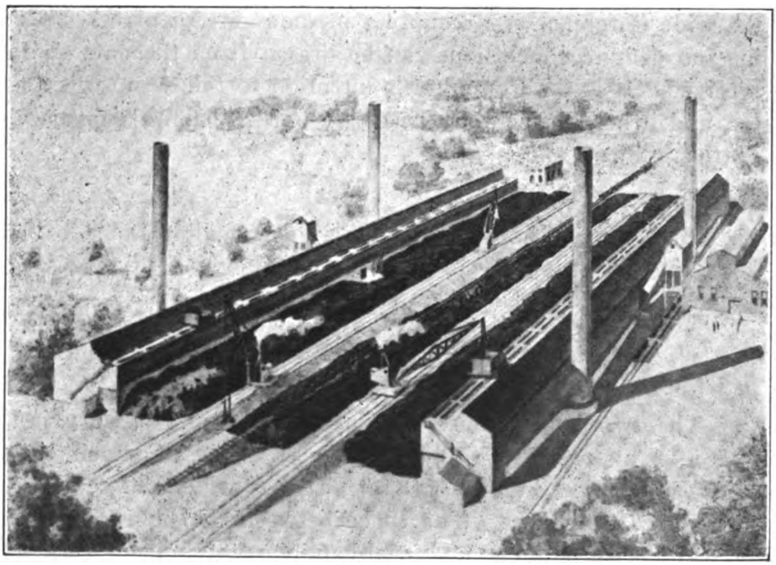

FIG. 27—COAL HANDLING EQUIPMENT U, S. GOVERNMENT EXPLOSIVES PLANT, NITRO, WEST VIRGINIA

each crane when handling coal from the pit to one of the bunkers is 200 tons per hour.

Fig. 27 shows the general layout of the plant and the coal handling equipment.

U. S. Government Explosives Plant "N"
Old Hickory, Tennessee

Coal is delivered on three tracks laid on a one per cent grade with a sufficient length above and also below the dumping hoppers to hold 35 cars. The hoppers are so arranged that coal may be received from either hopper dumping or side dumping cars. Each hopper is 27 feet by 27 feet and delivers to a 42 inch apron feeder with a capacity of 150 tons per hour, which feeds the coal to a 36 inch by 36 inch two-roll crusher operating at 110 rev. per min. These crushers deliver to 24 inch belts operating at 300 feet per minute, each of which has a capacity of 150 tons per hour.

The above belts convey the coal to the first set of inclined belts which lift the coal to the top of No. 1 silo, a reinforced concrete tower 20 feet in diameter and 43 feet high. If the coal is to be delivered direct to the bunker, that is, without storing, it drops down through the silo onto the second set of inclined belts, then to the top and down through silo No. 2 onto the third set of inclined belts, which lift it to the top of the bunker, where by means of horizontal belts, each provided with a hand movable tripper, it is delivered to any part of the bunker. Each of the inclined belts is 24 inches wide and at a speed of 600 feet per minute has a capacity of 300 tons per hour.

If coal is to be stocked, it is diverted through a hole in the upper part of either silo, forming a pile from which it is dug by one of two cranes operating on a four rail track with a figure 8 shape. Each crane is 110 feet radius and provided with a 3.5 ton bucket and has a designed capacity of 200 tons per hour. Coal being reclaimed is dug from any part of the pile desired and thrown against the silo into which it passes through a hole in the lower part onto a feeder which delivers it onto one of the inclined belts for delivery to the bunker. The silos are of sufficient size so that in case later it were found necessary to store

only screened coal, the crushers and screens could be installed in them.

All of the motors except those driving the conveyors on top of the coal bunker are equipped with automatic starters wired to a central control point near the coal hoppers, so that the entire system could be operated from that point. Chutes with proper gates are provided wherever necessary so that any belt can deliver to any of the subsequent belts, thereby giving

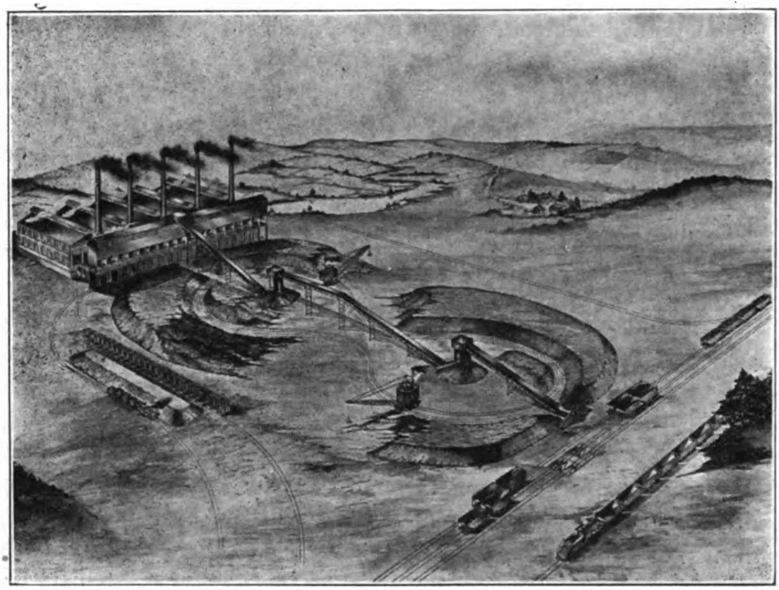

Fig. 28—Coal Handling Equipment, U. S. Government Explosives Plant, Old Hickory, Tennessee

excellent flexibility. Fig. 28 shows the general layout of the plant and the coal handling equipment.

Riverside Station of the Municipal Gas Company Albany, N. Y.

Coal is brought to the station by rail, a spur track from the Delaware & Hudson Railroad running the full length of the property. The coal is dumped from the cars into a pit from which it is picked up by an electrically operated traveling one man tower located on top of the boiler house structure and is

discharged into a hopper placed over a crusher in the tower, from which the coal drops through hatches into the bunkers. This tower has a capacity of 45 tons of coal per hour. The pile of coal within reach of the bucket is sufficient for ten days' supply for the boilers in addition to what is carried in the overhead bunkers. The traveling tower is illustrated in Fig. 29.

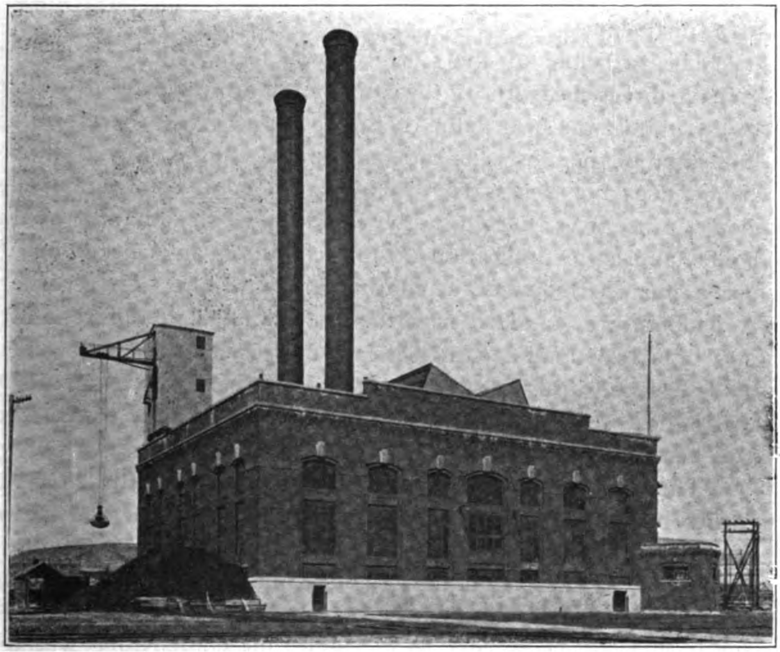

FIG. 29—COAL HANDLING EQUIPMENT, MUNICIPAL GAS COMPANY, ALBANY, N. Y.

BOILER AND TURBINE ROOM INSTRUMENTS

In the work of previous committees on boiler and turbine room instruments, recognition has been given to the use of CO_2 recorders and steam flow meters as an aid in the proper operation of the boiler room. Since these reports were made, such instruments have been much improved and other instruments have been developed to aid in the more efficient operation of both turbine and boiler rooms.

In the last two or three years great advancement has been

made in the development of CO_2 recording machines, and many of the former criticisms have been met, but at the present time these machines are still far from ideal for the fireman's use. Much trouble is experienced in keeping the machine and sample piping in working order, and there is a gradual falling off in the accuracy, beginning immediately after being put in proper repair. The reliability of the readings then depends upon the frequency of adjustment.

The principle of the CO_2 recorder is excellent in that it gives a direct measure of the amount of air required to utilize to the utmost the heat value of the fuel, and gives, therefore, an indication of the most efficient combustion. But good over-all efficiency does not necessarily follow from good combustion efficiency, since it is affected by the condition of the surfaces of the boiler, and as an indication of this condition, it is necessary to use a flue thermometer in conjunction with the CO_2 recorder. A temperature standard may then be obtained at different ratings by a test upon a clean boiler using proper combustion, and by reference to this in subsequent operation the flue temperature will indicate when the boiler is dirty. A steam flow meter then also becomes a necessary part of the outfit.

The same functions which are performed by the CO_2 recorder in conjunction with the flue gas thermometer and steam flow meter can be performed by other reliable means, as will be explained. While maintaining the maximum efficiency, a definite amount of combustible must be consumed to produce a definite output for the boiler and to consume this combustible will require a definite amount of air. If the relationship between the amount of air and the boiler output is determined once for all when the boiler is clean and operated at maximum efficiency, this relationship will subsequently serve as a standard by which to operate the boiler. The output of the boiler at any particular moment is proportional to the steam output, provided the feed water temperature is maintained constant and the rate of feed to the boiler is maintained proportional to the steam output.

In holding operation to the standard relationship, account must be taken of the condition of the boiler surfaces. If the surfaces are dirty, the gases must be hotter so that the water may obtain the same transfer of heat through the tubes, and this

will require more coal. There is then an increased amount of coal for the same output, and if the relationship of air to steam is held according to the standard, there will be insufficient air for the increased combustion. There is then a falling off in over-all efficiency chargeable to these two sources: that is to the inefficient heat transfer in the boiler and to the inefficient burning of the coal. The flue thermometer may be used to indicate this condition. The higher temperature of the gases will be evident in the flue, and by comparison with the temperature known as standard for efficient operation at equivalent rating, the condition of the tubes is indicated.

It would seem that this method of operating the boilers depends upon keeping the boilers clean. However, the transfer of heat through the boiler is as much a part of the elements operating toward efficiency of the unit as is the proper combustion, and requires attention to that end.

Air Flow Meters

To accomplish the purposes described, many methods have been devised for measuring the air passing through the boiler. In some cases it has been determined by means of pitot tubes, in some cases by orifices in the pass to the air chamber, and in others by using the boiler setting as an orifice.

When the latter method is used, the orifice becomes smaller as the gas passages grow dirty, and the differential indication given by the boiler-orifice is too high as a measure for the actual amount of air. The fireman then reduces the draft in order to maintain the standard ratios of air to steam and this condition augments the condition of insufficient supply of air caused by dirty heating surfaces, which has been previously explained.

The principal cause of the decrease of the size of the orifice is the formation of slag on the lower rows of tubes in the first pass, and in order to overcome the change in orifice where slag forms, it has been found necessary to place the draft pipe for the differential actuation above several rows of tubes in the first pass of the boiler. It is a question whether or not this is advisable; whether it would not be better to leave the draft pipe below the lower rows of tubes and to instruct the fireman to run in his bar and break off the slag when the temperature appears too high for the amount of steam produced, thus bringing the

orifice back to the normal condition as well as making his boiler more efficient and of undiminished capacity.

If the draft in the fire box is too great, there will be a tendency to blow through the doors when opened and the maintenance expense of the fire brick and grates will be increased, and if the draft is too low, the tendency will be toward a vacuum in the furnace and infiltration will be accentuated. Holding about

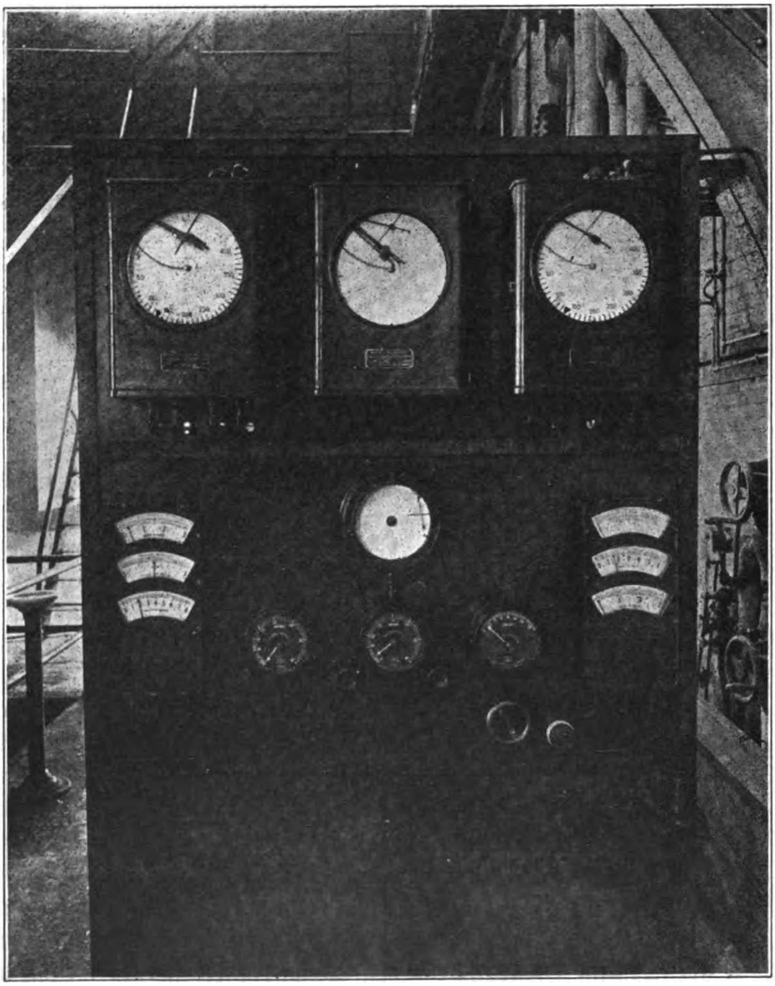

FIG. 30—BOILER CONTROL PANEL

1-10 inch water draft in the fire box on forced draft stokers has been found advisable for these reasons. Where this is adhered to and where the coal burned and the design of the furnace are such that no slag forms on the tubes, the draft in the last pass can be used as a direct measure of the amount of air passing through the furnace, eliminating the necessity for a differential pressure measurement.

Remote Control

The method of utilizing steam flow and air flow meters and flue thermometers offers a most promising solution to the question of boiler operation at the present time. If it is perfected to a greater degree, it will develop the principle of the remote control of boilers. We are entering into a period when one man will operate all the boilers from a central point.

By reference to Figs. 30 and 31, it will be seen how several

FIG. 31—INSTRUMENT BOARD IN OPERATING ENGINEER'S OFFICE

companies are gradually progressing toward this method of operation. All of these companies use one or the other of the methods just described, that is, the CO_2 recorder, steam flow meter, and flue gas thermometer, or the steam flow meter, air

flow meter and flue gas thermometer, together with indicating or recording draft gages, giving the pressure in the fire box, the draft over the fire and the draft in the last pass of the boiler.

Boiler Over-All Efficiency Measurement

Another instrument universally used is the tachometer which gives the speed of the stoker. This may be graduated in various ways to give seconds per revolution, coal per hour, or inches of air to be maintained in fire box corresponding to the speed. With provisions for measuring the amount of coal fed to the furnace, the amount of steam produced and the efficiency of combustion of the coal, the over-all efficiency is at all times indicated or recorded as the case may be, and the fire is completely and properly under control.

Some attempts have been made to indicate or record on one instrument the various conditions which have been described and which have a co-relation with one another to efficient operation, in order to avoid the use of several charts for interpretation, and considerable success is being experienced along this line.

Having considered the methods employed for operating boilers at maximum efficiency, it may be well to mention briefly some observations with regard to the instruments employed.

Steam Flow Meters

The steam flow meter has progressed greatly since the last report of this Committee, and its accuracy as now designed can easily be maintained within 2 per cent.

These meters then may be depended upon for a perfect indication in the boiler room, and also may be used in many cases for the sale of steam.

There are two principles used in the measurement of steam by the best known steam flow meters. One is based upon the orifice method and the other upon the pitot tube. Both of these are accurate in results. The pitot tube has one disadvantage over the orifice. If there is foreign material being carried along in the steam, it is apt to clog the openings and cause the meter to read in error. However, where there is no danger from this element, the pitot tube is just as accurate and reliable as the other.

It might be well to point out here to the users of steam flow meters who have had trouble with the clogging of pitot tubes that this form of meter could be easily and inexpensively changed over to the orifice type of meter, and the change would be readily made by any meter concern. This change. however, should be made by someone who thoroughly understands the characteristics of the flow of steam through an orifice, in order that the connections for measuring the differential pressure can be made in the right way and inaccuracy on this account avoided.

Boiler Plant Efficiency Measurements

Coming now to a discussion of the over-all efficiency of the boiler plant, the instruments used have progressed in proportion with those used for individual boiler operation. Very suitable meters have been designed for measuring the feed water supplied to the boiler. Also meters for measuring the water that is drawn from the boiler in the form of blow-down. Furthermore, recording automatic scales have been developed for recording the weight of coal passing over belt conveyors or through hoppers, so that it is possible to run continuous over-all boiler room tests.

Automatic instruments for measuring coal, however, have not reached the stage of perfection which could be desired, as in order to keep them reasonably accurate they must be continually adjusted. For this reason many plants equipped with the modern boiler of increased size are using the coal larry with the well known platform scales.

Recording thermometers are coming into more extensive use in various parts of the plant. The installation of economizers calls for the employment of these and they have proved accurate and essential for efficient operation at this point.

As a matter of fact, regarding all turbine and boiler room instruments, the recording type is becoming popular and shows good results from the point of view of decreased cost of operation of the plant.

Water Meters

The meters used for measuring the feed water may be divided into different classes, one which employs the principle of the V notch weir, another the principle of the orifice and an-

other the principle of the pitot tube, and there are also meters depending upon weighing devices and volumetric meters.

The pitot tube has the same faults in measuring water that it has in measuring steam and for this reason it is practically eliminated from this class of service.

The orifice type of meter, which includes the Venturi type, is an accurate means for measuring hot water and is extensively used. The V notch weir, which has greatly advanced in recent years, is pressing the Venturi meter for a place in this field and its accuracy and practicability have become unquestioned. These types may also be used for measuring the water which is taken from the boiler in the form of blow-down. All three of these types of meters with very little attention can be kept well within the accuracy of 2 per cent.

Indications for Special Purposes

The Station Load Indicator has a place in every boiler room and turbine room. This is sometimes of the taxi-call type, but many plants have devices of their own design.

Indications for special purposes in various plants are of value. Among member companies it is noted that thermometers have been used on super-heaters where there is trouble from priming of the boilers, in order to give an indication of this trouble. Water back alarm thermometers are used by some. Damper position indicators find some use.

Turbine Room Instruments

Turbine room instruments have also made considerable advance. We need say nothing in regard to the thermometers, steam gauges, speed indicators, etc., which have already become so common, but with the improvement which has taken place in the steam flow meter it has become more and more desirable to equip each unit with a steam flow meter, and by this means an accurate account may be kept of the disposition of the steam produced and a reliable indication given of any trouble which has developed or is developing in a particular piece of apparatus as shown by the increased steam consumption.

Among special devices used by some in the turbine room, mention should be given to the air bell in connection with condensers as a measure for leakage.

Mention should also be made of the two pen recording thermometer used on jet condensers in certain cases, showing exhaust steam and circulating water discharge temperatures.

Electrical instruments have long ago reached a pretty complete stage of development. Instruments for the assistance of the fireman and the engineer on the other hand are of comparatively recent development. They are still in an incompleted stage of the process. Many plants have still to learn the value of these instruments. Many others wait only to be assured of their value from the point of view of their reliability.

We are in a forward movement which has developed rapidly and still has the momentum for further improvement in instruments and methods. If we would go forward with this movement, we must be a part of it, and the development is so far advanced today that money cannot be better expended in the plant than by equipping the station pretty thoroughly with instruments as advocated in this report.

Pulverized Fuel

The use of pulverized coal as fuel for industrial work and under steam boilers has received a great deal of attention from central station operators as well as manufacturers during the past few years, due to the rapid decrease in the supply of natural gas for fuel in heating furnaces and similar industrial work and the scarcity and high price of fuel oil, as well as the rapidly increasing cost of coal, together with its poor quality.

The burning of pulverized fuel for industrial work has developed to a point where the difficulties have been largely overcome, but your Committee has very little to report on the successful use of pulverized coal as fuel under steam boilers for central station work.

Several installations have been made for burning pulverized fuel under boilers in central stations, but these installations have been made principally under small boilers in old or rebuilt stations.

Possibly the application of the art has not been given the fair trial to which it is entitled, but no installation of this equipment has been made in a modern central station or under large boilers where it could be definitely proved that the system meets

the demands of the central station or can successfully compete with the modern stoker, either in efficiency or capacity to meet the present day requirements.

The problem of the manufacturer who has a steady load and a comparatively continuous output of his product is entirely different from that of the central station operator who is called upon to meet almost instantaneous demands for steam which require him to operate his boilers at from 100 to 400 per cent of rating.

Whether or not the manufacturer of pulverized fuel equipment can produce apparatus to compete with the various types of stokers, which are now meeting these demands so successfully, remains to be proven.

The manufacturer of pulverized coal equipment makes claim to the following advantages over hand-fired furnaces or stoker-fired furnaces:

1. Maintenance of high thermal efficiency in the combustion chamber, irrespective of the ash contents or analysis of the coal or the rate of combustion within very wide range.
2. The furnace construction is such as to keep high temperature zones away from refractory brickwork, hence insuring maximum life of the same.
3. Maximum results from the human element. The fireman is freed from slicing, barring, leveling, cleaning, and dumping fires, and from many other duties necessary with other methods of mechanical stoking and burning fuel on grates or in retorts; freeing him from arduous work provides time for closer observation and recording of boiler operation.
4. Elimination of smoke, dust, gas fumes, and firing tools from the furnace room.
5. Elimination of grates, stoker and all other metal work from the furnace.
6. Elimination of clinkers, slag and combustible in the ash, and the minimum amount of ash to handle, due to the fact that the ash is carried up the stack in the form of powder.

On the other hand, the manufacturer of stokers makes claim to the following advantages.

1. Less cost of installation per boiler horsepower.
2. Instantaneous response to power station demands for steam.
3. Low cost of operating stokers against the high cost of the auxiliary equipment in connection with pulverized fuel.
4. No space required for pulverizers or driers.
5. Smokeless combustion.
6. High thermal efficiency.

One of the prominent manufacturers of pulverized fuel equipment, however, has announced that a contract was recently closed for their equipment to be used in connection with two 1200-hp. boilers which will soon be installed in a new modern central station.

Results obtained from this installation will be carefully investigated by your Committee and reported upon in due time. Until some data on the operation of this equipment are available, the Committee is without recommendation.

Résume of the Fuel Oil Situation

The output of petroleum from the major fields for the years 1917 and 1918 is shown in the following table which is a preliminary estimate made by Mr. John D. Northrup of the U. S. Geological Survey, Department of the Interior, January 10, 1919.

Quantities of Crude Petroleum Marketed in the United States

Field	1917 Barrels	1918 Barrels
Appalachian	24,932,205	25,300,000
Lima-Indiana	3,670,293	3,100,000
Illinois	15,776,860	13,300,000
Oklahoma-Kansas	144,043,596	139,600,000
Central and North Texas	10,900,646	15,600,000
North Louisiana	8,561,963	13,000,000
Gulf Coast	24,342,879	21,700,000
Rocky Mountain	9,199,310	12,600,000
California	93,877,549	101,300,000
Alaska and Michigan	10,300	—
Total	335,315,601	345,500,000

The year 1917 held the high record for production, and it will be seen that the production for the year 1918 is an apparent gain of 3 per cent over the previous year.

This increase in output was made in response to a steadily growing demand for petroleum that resulted in advancing prices, which were finally stabilized with government approval but at record levels during the closing months of 1918.

As indicated in the foregoing table, the most pronounced response to the stimulus of war-time demand was in the Central and North Texas, the North Louisiana and the California fields. Momentous developments which have already affected and will continue to affect the future supply of high-grade petroleum in this country took place during 1918 in the Central and North Texas field after petroleum had been discovered the previous year in Eastland, Stephens, Brown and Coleman Counties. In these districts about 60 oil wells were drilled during 1918, and at the end of that year these fields were credited with a potential capacity of 50,000 barrels per day, although, due to lack of pipe line facilities, an actual capacity of but 18,000 barrels per day was attained. The campaign of drilling radiating from these fields, extending over more than 40 counties in Texas, will no doubt result in the opening of other high-grade pools in 1919.

The production of domestic petroleum during the past year amounted to about 366,000,000 barrels, and the exports of crude oil, most of it to Canada and northwestern Mexico, aggregated about 5,500,000 barrels, leaving a total of 360,500,000 barrels available to supply domestic needs. This quantity was insufficient and about 36,500,000 barrels were imported, nearly all of it from Mexico, to meet the domestic requirements, which amounted in all to about 397,000,000 barrels.

This enormous demand was due to many causes, many of which were directly or indirectly the result of industrial conditions brought about by the war. The immense increase in railroad traffic had its influence on the demand, as even in 1917 the U S. Geological Survey estimates that there were used almost 46,000,000 barrels of oil by oil-burning locomotives, which is an increase of 8½ per cent over the quantity used in 1916. The U. S. Shipping Board during the year 1918 used large quantities

of oil to fuel ships and will use more oil for that purpose as evidenced by the fact that it has stated, as late as March 16, 1919, that it may require as much as 34,000,000 barrels to fuel ships during the coming year. The Navy also used enormous quantities for the vessels under its control, especially when this oil had to be transported overseas in oil-burning vessels before it could be used by war-vessels.

The gasoline requirements generally, and particularly the requirements of the Army and Navy Aviation Forces and the Army Motor Transport Service, contributed not a little to this enormous oil consumption, since gasoline is a refined product of petroleum. The speeding up of munition work of all kinds in manufacturing plants using oil for power and heat treating purposes had the effect of an increase in oil consumption, which was further increased by the fact that many manufacturing plants substituted oil for coal under boilers due to the difficulty encountered in obtaining coal.

These factors resulted in bringing the oil consumption for the year up to 397,000,000 barrels which, with a production for the year of but 345,500,000 barrels, resulted in a depletion in the storage at the end of the year of over 50,000,000 barrels.

During the present period of transition following the cessation of hostilities there has been evidenced a slackening demand for oil with a resulting softening of prices. With industrial conditions unsettled as they are at this time, it is hard to tell definitely what conditions will obtain in the oil market during the coming year, but there probably will be an adequate supply of fuel oil and at prices somewhat lower than at present.

In the report of the Prime Movers Committee for the year 1913, under Appendix E a very comprehensive article on the subject of "Fuel Oil and Its Combustion" was presented by Arthur D. Pratt.

This article is well worth the study of anyone who is interested in oil firing as it covers in detail much useful information on this subject, including in its text the calorific value of different grades of fuel oil available in this country, the advantages to be obtained from oil firing, together with suggestions for getting the best economies with different types of burners and furnaces. It also gives tables showing the relative value of coal and oil fuel.

Burning Lignite

Interest in the possible use of the large deposits of the younger, low-grade fuels of the west was stimulated by the unusual conditions brought about by the war, and some progress can be reported in the art of burning them in boiler furnaces. This is especially true in the case of lignites, with which less had been done than with the sub-bituminous coals.

Although these two types of fuel have many common characteristics and present somewhat similar combustion problems, the higher moisture content and lower heat values of the lignites make it advisable to differentiate between them. The following analyses are fairly typical and illustrate the differences mentioned.

	Sub-Bituminous Coal from Boulder County, Colo.	Lignite Coal from Wood County, Tex.
Moisture	18.68%	33.71%
Volatile Matter	34.88	29.25
Fixed Carbon	40.45	29.76
Ash	5.99	7.28
Sulphur	0.55	0.53
B.t.u. per lb	10,143	7,348

Storage

The problem of storage is so closely related to the use of these fuels on any considerable scale, and especially in large central stations, that it is regrettable that so little data on the subject is available. It is generally accepted that either lignites or sub-bituminous coals, when stored in open piles of large size or depth, will fire spontaneously within a period of, perhaps six months.

Bureau of Mines (U. S.) Bulletin No. 136, reports on experiments conducted several years ago with Sheridan (Wyo.) sub-bituminous coal stored in wooden bins. Cracks between the boards permitted access of air, which evidently penetrated the mass of stored fuel. The report has more to do with deterioration than with heating. In nine months, loss of heating value occurred to the extent of 2½ to 4 per cent. Slacking also took place and apparently in proportion to the extent the air permeated the mass. No evidences of heating were noted in these experiments, but another Wyoming sub-bituminous coal stored under similar conditions is known to have set the sides of the

bin afire. No data are available as to what these fuels would do in a bin with tight sides and bottom.

At the plant of the Fort Worth (Tex.) Power & Light Company run-of-mine Texas lignite was stored in an open pile and in a bin having practically air tight sides and bottom. The open pile contained about 75 tons, had a maximum depth of 12 feet, was square in shape and had the sides boarded up to a height of 3 feet. This fuel was in storage about four months in the summer of 1918, at the end of which time the pile was accidentally set afire by external causes and the test was discontinued. During the four months frequent temperature measurements throughout the pile failed to show any serious heating.

The bin used for the other experiment was 10 by 10 feet inside and 12 feet deep, and this was filled in May, 1918, with run-of-mine lignite from the same source. In this case the air-slacking of the top surface of the fuel in the bin was depended on to restrict the access of air to the fuel farther down, and thus to control the spontaneous heating. Temperatures began to develop in this bin in about a week, reaching a maximum of 180 deg. fahr. within a month. This maximum was maintained for some weeks, but later dropped to about 75 deg. Examination of the fuel after six months storage showed that very little disintegration or slacking had taken place except in the upper 18 inches of the bin, and a sample taken 3 feet below the top surface and across the bin showed practically the same analysis and heating value as when stored.

Combustion in Hand-Fired Plants

Hand-fired plants depending upon sub-bituminous or lignite coals for their fuel supply are usually small and, so far as the Committee knows, little real study has been given to the problem of burning such coals under these conditions. Both types of fuel disintegrate rapidly under the action of heat in the furnace and have the characteristic of easy and rapid distillation of the volatile matter. The problems of hand-firing are, therefore, the prevention of excessive sifting of partially-burned fuel into the ash pit, and the improvement of furnace design and methods of operation so as to secure complete combustion of the volatile matter.

Grates of the herring-bone or pinhole type. having small sized openings and rather low percentages of air space are usually required to overcome sifting difficulties. Ordinarily the stack draft available in these small plants is inadequate, and higher stacks or forced draft equipment should be supplied.

Relatively large furnace and combustion chamber volumes and the proper admission of supplementary air over the fire are necessary for preventing incomplete combustion losses. Especially for natural draft conditions, relatively large grate areas are necessary for generous ratings, on account of the low thermal value of the fuel.

At the Williston (N. Dak.) plant of the U. S. Reclamation Service a sort of gas-producer type of furnace is in operation with lignite as fuel. Under test conditions this installation showed combined boiler and furnace efficiencies ranging from 50 to 60 per cent, and practically the same range of efficiencies was obtained with similar lignites under what might be termed standard hand-fired test conditions at the Government fuel testing plant at St. Louis.

Combustion in Mechanically-Stoked Plants

The greater part of the tests conducted with these fuels on all types of stokers was made in furnaces designed primarily for other fuels. This should be kept in mind more especially with regard to the results with lignites, because their high moisture content complicates the difficulties of ignition.

It is also important to remember that the B.t.u. values usually quoted for these fuels are the so-called "high" values and include the latent heat of vaporization of the moisture content of the coals. If deduction be made for the heat required to bring this moisture to the boiling point, evaporate it, and superheat to 550 deg. fahr. (temperature of products of combustion leaving the boiler) the values for sub-bituminous coal would be approximately 2½ per cent lower, and for lignites nearly 6 per cent lower.

Attempts have been made to burn these two kinds of fuel on mechanical stokers of the front or side over-feed type designed primarily for bituminous coals. So far as is known these attempts have been uniformly unsuccessful, and a change of the

angle of the stoker grate surface, as well as a redesign of the grate, would probably be necessary before the present difficulties from avalanching and sifting would be overcome.

In stating what progress has been made in burning these fuels, stokers may be grouped into two classes: (1) those employing natural draft, and (2) those with forced draft equipment.

Natural Draft Stokers

Practically the only natural draft stoker that has been used much with sub-bituminous and lignite coals is the chain grate. The former of these fuels is fairly well suited to chain grate operation, and rates of combustion of almost 40 lbs. per sq. ft. of grate surface per hour are reported by the Green Engineering Company. Excellent boiler and furnace efficiencies are quoted by the same Company under test conditions but no heat balances on these tests are available, nor is any information at hand as to the furnace design for these installations.

Rates of combustion of 30, or possibly 35 lb. per sq. ft. per hr. of grate surface have been considered about the maximum obtainable with lignites on chain grates under natural draft conditions. In recent experiments at Fort Worth (Texas), however, more than 60 lb. per sq. ft. was attained. In this case an ignition arch 3 ft. 0 in. above the grate at the front, 3 ft. 9 in. at the rear, and 8 ft. 9 in. long was employed. The opening between the bridgewall and the end of the arch was 2 ft. 9 in. and the header height was 9 feet 0 in. above the floor line. Evaporation test results are not yet available on this installation, but a refuse low in combustible is reported under the above rates of combustion. Combined efficiencies of about 67 per cent with Texas lignite are reported by the Green Company for tests run several years ago.

The temperatures developed in chain grate furnaces with these fuels under natural draft conditions are not high, and in the case of lignites are probably not over 2200 deg. fahr. even under the high rates of combustion mentioned. This would seem to warrant the expectation that no difficulty would be encountered with side wall clinkers, and the limited experience with lignites bears this out. It is possible that a reversed arch (extending from the bridgewall towards the feed gate) will produce more

reliable ignition and better combustion conditions, and, if properly ventilated, such an arch may prove satisfactory from a maintenance standpoint.

With this type of stoker, provision must be made to restrict the admission of the excess air that would naturally enter at the rear of the chain and between chain and bridgewall.

Forced Draft Stokers

At the present time experience with forced draft stokers is limited largely to the inclined retort underfeed design, and more results are available for sub-bituminous coals than for lignites. The consensus of opinion of stoker manufacturers appears to be that lignite burning presents greater difficulties than sub-bituminous coals, and that better results are to be expected with the latter fuels.

The Sanford Riley Stoker Company states that the combined efficiencies obtainable will be lower than for eastern high grade bituminous coals, the reduction amounting to ½ to 1½ per cent for each 1000 B.t.u. difference in heating value as compared with the eastern coals. This figure seems to be fairly well borne out by recent tests with lignite.

What information is available tends to show that, as with the natural draft stokers, the furnace temperatures developed with both types of fuels are relatively low. In the case of the lignites the maximum is about 2300 deg. fahr. In general, clinker troubles are not serious. Most of the fuels of these two types are relatively low in ash so that the quantity of refuse is not great. Such clinkers as are formed are usually of light weight and easily broken when hot or cold. With the underfeed type of stoker and at the higher rates of combustion, in some cases clinkers are formed in the shape of a saddle over the tuyere boxes. Owing to the disintegrated condition of such fuels in the furnace, it is sometimes necessary to employ firing tools to assist the stoker motion in removing these clinkers from the fuel bed. On account of the low temperatures developed, the life of furnace linings is usually satisfactory.

The Combustion Engineering Corporation reports tests of a Coxe traveling grate stoker of 107 sq. ft. grate surface, set under a 4640 sq. ft. Stirling boiler, showing a combined effi-

ciency of 72 per cent at 160 per cent of boiler rating, with Sheridan (Wyo.) sub-bituminous coal; but no data are at hand for checking this test. A stoker of this same type is installed for tests with lignite at Fort Worth (Tex.) but no results are yet available.

A test of Colorado sub-bituminous coal in a Taylor stoker at the Cedar Rapids plant of the Iowa Railway and Light Company was made in 1915, showing 61 per cent combined efficiency. As a result of more recent experiences, the American Engineering Company states that with fuels of this nature efficiencies somewhat above 70 per cent are obtainable, and similar figures are quoted by the Westinghouse Electric & Manufacturing Company and the Sanford-Riley Stoker Company. All of these manufacturers state that even for high rates of combustion ignition arches are not required with sub-bituminous coals, and that maximum capacities of 250 per cent of boiler rating may be relied upon. These coals are also well suited to quick steaming demands.

Opinion among the stoker manufacturers apparently differs as to the need for an ignition arch for burning lignites in underfeed stokers. The stoker recently installed at Fort Worth by the American Engineering Company is set with an arch 4 ft. 3 in. long placed about 3 ft. 0 in. above the stoker. This furnace was designed for burning lignite of 33 per cent moisture content. On the other hand, the Sanford-Riley Company reports experience in burning lignite having up to 28 per cent moisture and does not consider an arch to be necessary. Maximum capacities of approximately 250 per cent of boiler rating are reported by both of these companies with lignites. Tests at the Fort Worth Power and Light Company have shown about 69 per cent combined efficiency at boiler rating and 60 per cent at 200 per cent of rating.

Wind-box air pressures employed for both types of these fuels with underfeed stokers are considerably less than for bituminous coals, and range from ¾ in. at rating to approximately 2 in. as a maximum. Higher pressures tend to blow holes in the fuel bed and to throw excessive amounts of partially burned fuel on the dump plates. In order to minimize the latter difficulty, the port area in the tuyere plates should be

divided into a number of small distributed openings. Large ports directed towards the bridgewall are to be especially avoided.

Conclusions

There is still much to be learned about the burning of both lignites and sub-bituminous coals in the raw state. This is especially true of lignites. There appears to be no reason why the better grade sub-bituminous coals, such as those from Colorado and Wyoming, should not be used successfully in many localities, providing satisfactory ways can be found for storing them.

Because of the higher moisture content and lower B.t.u. values of the lignites and the lower boiler efficiencies obtainable with them, it is more probable that in the future they will be burned in some modified form, viz., dried, pulverized. or carbonized, except within certain limited areas where transportation costs are low.

Storage of either of these types of fuel without danger of spontaneous combustion seems to be a possibility after further study of the problem.

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Coal By-Products

The subject of the extraction of by-products from coal before burning under boilers has been discussed during the past

year to a considerable extent abroad, particularly in England, but not to any great extent in this country. Probably the reason for the amount of discussion in England was due to the fact that England during the war—particularly at its start—was very short of toluol and benzol, by-products which are necessary ingredients in the manufacture of munitions. Toluol and benzol are by-products which are not recoverable when coal is burned directly under boilers, but they are recoverable from the various processes of carbonizing coal. It is but natural, therefore, that when the shortage of these materials was acute, there should be much discussion and many schemes advanced whereby they could be conserved.

In this country coke was originally produced in "bee-hive" ovens located in fairly close proximity to the coal mines and to a large extent is so produced today. In this process all of the gas and by-products contained in the original coal are lost, but the process, though wasteful, has the advantage of very low investment cost and low operating charges. As a result of the wastefulness in the "bee-hive" oven manufacture of coke, there has been developed the By-product Coke Oven in which are recovered the by-products lost in the "bee-hive" ovens.

The by-product coke oven industry has made great strides during the past few years and no doubt will continue to make increasingly greater strides in the future. The first cost of such plants, however, is very high, and in order that the plant may be operated at a profit there must be a market, not only for the coke produced, but also a nearby market for the gas generated and for the other by-products such as ammonia, tar and light oils.

In the blast furnaces of the steel industry coke is the only form in which carbon can be used successfully, and therefore in that industry a ready market is found for the coke. Coke is not used, however, under the boilers in that industry, or in fact in any other industry, because it immediately comes into economic competition with and loses to both anthracite and bituminous coals. Coke, moreover, because of its comparative light weight per cubic foot would require larger boiler grate area per unit of power than coal and also larger storage space than coal, and existing boiler designs would have to be further modified

because of the fact that coke contains practically no volatile matter.

There are certain grades of coal so poor that it is difficult to burn them successfully under boilers, but these fuels may be used in such systems as the Mond process, which is a producer gas process with a partial recovery of by-products. This producer gas in turn may be used as a fuel to replace coal fired under boilers. However, when the efficiencies of the gas producer plant and the steam boiler are combined, the resulting efficiency is lower than average boiler efficiencies. It may thus be seen that where these poorer grades of coal can be burned directly under the boilers it is economically wrong to use such coal to make producer gas to be used solely as boiler fuel.

In conclusion it may be said that today there is a well-established industry, the by-product coke oven industry, wherein there is produced a solid fuel containing a high percentage of carbon together with a marketable gas and other marketable by-products, but the coke produced cannot now compete economically for steam-raising purposes with either anthracite or bituminous coal and, moreover, the coke will not be able to compete economically with coal for steam-generating purposes until its selling price is reduced, which can be accomplished only by a higher price for the by-products obtained.

Higher Steam Pressures

The reports of the Prime Movers Committee presented at the Conventions held in 1916 and 1917 gave a brief, comprehensive outline of the possible economies to be obtained by going to the so-called higher steam pressures, the principal difficulties to be encountered and a statement on this subject from some of the leading manufacturers of boilers and turbines. Since then, little actual progress has been made, chiefly because the thoughts and energy of every one have been devoted toward winning the war.

The project is by no means dead and, during the interval, the Buffalo General Electric Company has placed in service a plant designed to be operated at 275 lb. boiler pressure and 275 deg. superheat, giving a total temperature of 689 deg. fahr. The Public Service Company of Northern Illinois has installed

and is operating a plant with a boiler pressure of 315 lbs., and 225 deg. superheat, giving a total temperature of 651 deg. fahr., and the British Thomson-Houston Company has had in operation in its works at Rugby, Eng., a small boiler plant operated at about 350 lbs. pressure and with such superheat that the total temperature ranges from 700 deg. fahr. to 750 deg. fahr. at the boiler.

While minor troubles have been encountered at all of these installations, such as might be anticipated when the pressure and temperature of the steam system are increased, your Committee is advised that in each instance the installation is considered generally satisfactory

There have been practically no troubles with the boilers or turbines, due to the changed steam conditions. Flanged joints in the steam piping lines and under the bonnets in the gate valves proved more troublesome to install and maintain. The small valves, gage cocks and like apparatus, which usually are more troublesome to maintain than the larger apparatus have required much more attention. Minute blowholes in valve bodies, fittings, etc., which would not be expected to give trouble on lower pressures, have shown troublesome leaks on the higher pressure. These are all things which should be expected and are usually cured as soon as there is sufficient demand on the manufacturers to justify the developing of apparatus for the new conditions.

These installations. however, are but a step in the direction that it is possible to go, and in analyzing these possibilities, it is first necessary to see what are the limits and then the possibilities of approaching these limits. The first limit is undoubtedly the boiler. The Babcock & Wilcox Company advises your Committee that the statement submitted by the Company in the 1916 report covers the situation today and that it has nothing further to add at this time. The Company states that the intervening war period has very much interfered with its experimental work, and although these experiments have been continued they necessarily have been made under very adverse conditions and nothing further can be added at this time on the possibility of building boilers for pressures higher than 300 to 350 lbs.

While it may be possible to increase the boiler pressure to almost any desired point by changing design, there is today a

very definite limit to the maximum temperature which it is safe to use. That is fixed by the steels now in commercial use, and appears to be between 600 deg. fahr. and 700 deg. fahr. This is

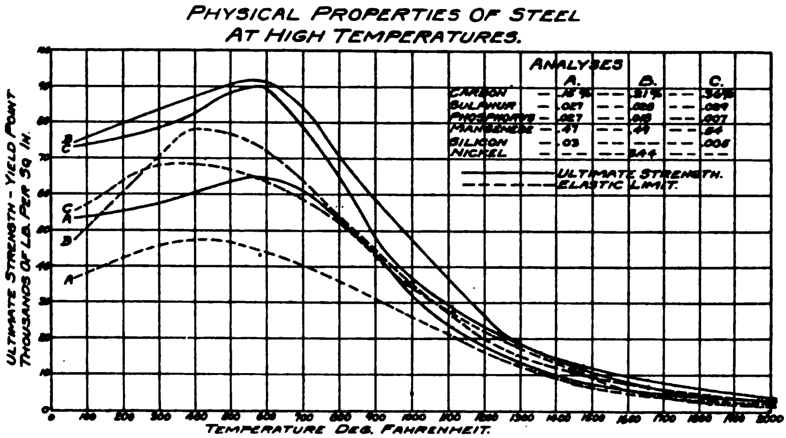

FIG. 32

well brought out by the curves shown in Fig. 32 and by the following statement made by Mr. Charles L. Huston, Vice-President and Works Manager of the Lukens Steel Company:

While we do not have records to indicate the service qualities of steel at temperatures higher than those at present in use, I believe I could say with a good deal of confidence that the use of soft carbon steel, say of 50,000 lbs. to 60,000 lbs. tensile strength, would be thoroughly safe up to temperatures of say, 600 deg. fahr. or safely under the critical temperature of steel, which varies very little between soft and medium hard steels.

I do not believe that the use of higher tensile strength steel in standard carbon steels would be desirable, for the reason that as the critical point in steel, say about 700 deg. to 800 deg. fahr., is approached, the metal becomes less ductile and would be more likely to crack.

I enclose a copy of the Journal of the Franklin Institute dated February, 1878, containing the results of experiments which my honored father made a number of years ago, and in which as a young fellow just beginning in the steel business, I participated, so that I not only have the records but the mental photographs of the different samples of steel and the way they looked when freshly fractured at these different temperatures.

In the above statement I am expressing my opinion simply in regard to standard carbon steels and not touching upon alloy steels, the behavior

of which at these high temperatures I am not familiar with, nor do I know of any experiments of similar character that have been made of recent years on such steels.

From the fact, however, that these old experiments showed very similar characteristics with chrome steel as compared with carbon steel, I have been led to infer that the same conclusions might be applied generally to all classes of steel, viz., that when you get up into higher temperatures it is desirable to keep soft, ductile material.

Many people, as you know, regard a piece of steel as an absolutely homogeneous mass of metal, whereas all steels consist of a mixture of ferrite crystals with various metalloids, usually carbide of iron, phosphide of iron and sulphide of iron, interlarded between the ferrite crystals, the ferrite having the highest melting point in the combination and the different metalloids requiring different degrees of temperature to fuse them. The greater the variety of metalloids introduced into the steel, the greater is the need of ascertaining the fusing point of these different metalloids, for the reason that when the steel is heated to a temperature where the weakest metalloid is either fused or its structure broken down by the heat, the strength or ductility of the whole mass is more or less impaired.

Therefore, I should be inclined to think that unless very elaborate experiments have been made and service tests obtained from any theoretical alloy steel that might be thought advantageous to use, it would be safer in the meantime to stick to soft steel of straight carbon quality, which carries the largest proportion of pure ferrite in its make-up.

The attitude of the Allis-Chalmers Company on the turbine end is clearly explained in the following quotation from its letter:

We would advise that our standard high pressure condensing steam turbine apparatus is designed for working steam pressure as high as 200 lb. gauge for the smaller machines and 250 lb. gauge for the larger ones. Therefore, for pressures of 300 lb. gauge and above some special development would be involved in each case. We find that our standard line of apparatus is suitable for practically all of the inquiries we receive. and as pressures above 250 lb. gauge would apply entirely to the larger units, the development to meet such pressures would not be excessive, as it is our practice to blade the larger machines for as near to actual operating conditions as our manufacturing standards will permit.

For temperatures above about 500 deg. fahr. we use a partial cast steel cylinder construction which we feel is suitable for maximum temperatures up to about 650 deg. fahr., above which temperature we have not attempted to go so far.

We do not find much tendency in this country to go above the normal operating temperature of about 600 deg. fahr., except in very extreme cases for large units and, with this temperature, steam pressures of 300

lb. gauge or 350 lb. gauge do not offer any difficulties or involve any considerable special development expenses.

The General Electric Company makes the following statement:

Turbines suitable for higher pressures can without question be produced without involving us in any complications by the time that boilers can be furnished for said pressure. It would appear that this matter is essentially a boiler problem. We can supply the turbines for you, if you can obtain the boilers.

A full discussion of the possibilities appeared in the paper by Eskil Berg on Advantages of Higher Pressure and Superheat as Affecting Steam Plant Efficiency, which was published in the *General Electric Review* of March, 1918.

The position of the Westinghouse Electric & Manufacturing Company is very clearly stated in the following quotations from its letters:

We look with favor upon the gradual upward tendency in steam pressures, but with moderation on the total temperature. In other words, speaking from the standpoint of the turbine alone, if the central station were ready with its piping and fittings and with its operating knowledge to use pressures of 300 lb. and above, we would say that we were ready with the turbine, and we would approve of the step being taken. With our present knowledge of power plant efficiencies, it seems as though any future material improvement must lie in that direction. We think your Committee can very well assume that the turbine is not or should not be one of your problems. We think perhaps that the practice will have to start with the large central stations. It will be a manufacturing handicap if we have to build both high pressure and moderate pressure machines. However, between the operators and the manufacturers it should always be possible to find feasible methods of doing anything that is sound and economically desirable. . . .

We wish to state that the effect of the higher steam pressure is to add very materially to the cycle. The efficiency of the turbine will become less because of the smaller volume and greater density of the steam at the high pressure end, and because of the greater quantity of moisture at the exhaust end. We would expect, in practice, a gain of steam consumption approximating that shown in curves Fig. 33 and Fig. 34, which were carefully worked up some time ago in the case of a 60,000 kw. turbine.

To date no turbines have been built adaptable for pressures beyond 300 lb. Some few are being built by this company for this pressure.

For pressures higher than 300 lb. newly designed turbines will be required. There will not necessarily be any change in type, but merely

additional elements to handle economically the added pressure range. Of course, steam chests and controlling valves represent some difficulties in design, but these seem to be by no means insurmountable. In this connection it should be noted that the valves will not be materially less in size because of the smaller volume of the steam. If the steam velocity

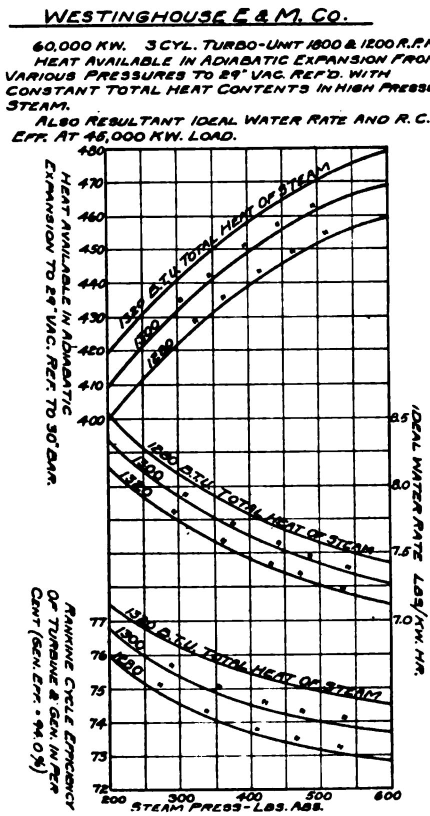

FIG. 33—OPERATING CHARACTERISTICS OF TURBINE WITH HIGHER STEAM PRESSURES

in the valves and piping were made inversely proportional to the density, the valves and piping would remain the same size.

We think the question as to what extent this company is prepared to go in furnishing turbines built for steam pressures higher than 300 lb. is as much a commercial consideration as one of engineering, considering the development costs involved. There is no doubt that turbines can be built for these higher pressures, and there will be gains in economy due to this, such as above outlined. I would say that if we attempt to design

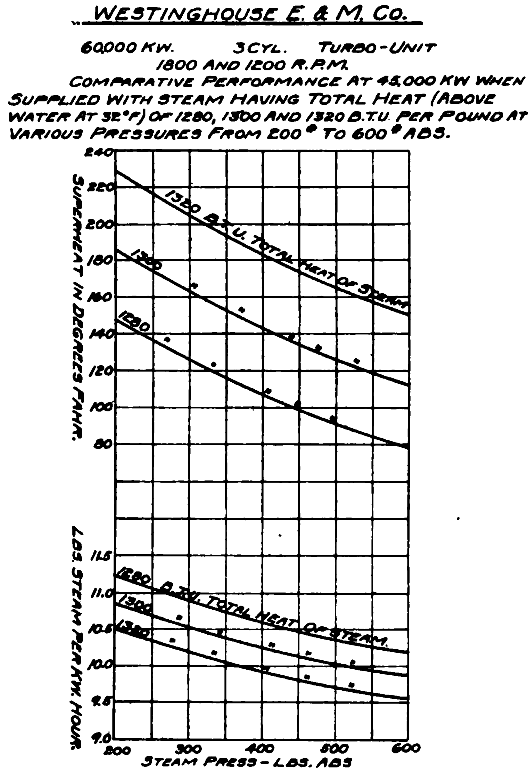

FIG. 34—WATER RATE OF TURBINE WITH HIGHER STEAM PRESSURES

turbines for these higher pressures we would prefer this to be brought about by an increase of pressure without material increase of temperature; that is to say, we would prefer a reduction in the superheat; for instance, 500 lb. pressure with a superheat that would give a total temperature not to exceed 650 deg., that is about 170 deg. superheat.

Apparently the manufacturers of steam turbines favor the movement toward higher pressures and are prepared to meet it, while manufacturers of boilers require time for further investigation and development work before they go much above the existing limit, which is around 350 lbs. The economizer situation is less satisfactory; the limit of pressure appears to have been reached with the standard cast iron economizer now in use. To go beyond this point would require either an entirely new type

of economizer, or an installation of the present type operated at a pressure much below that of the boiler, which would require running boiler feed pumps in series.

Little attention appears to have been given to adapting to higher steam pressures the various steam auxiliaries required in the installation. While these units are comparatively small in size, they are numerous and require proportionately more attention from the operating force than the larger units. It is just as important to avoid trouble with them as it is with the main prime mover. Your Committee is also unable to learn that manufacturers of valves, fittings and other steam appurtenances of the power plant have given any special thought towards adapting their apparatus for pressures much above those now common. It would, therefore, seem that there is much further development work to be done before a successful installation of pressures above those now in common use can readily be made. Very probably the initiative will have to come from the users, and when there is sufficient demand for improvements in the existing construction, the manufacturers will respond as readily and successfully as they have in the past.

Another factor which has a bearing on this project is the position that the Boiler Insurance Companies may take. Statements have been obtained from some of the leading companies on this subject. One company states:

We are pleased to advise you that the pressure for which the safety valves on steam boilers are set has no bearing on the rates charged for steam boiler insurance.

Steam boiler insuring companies require that steam boilers be so constructed and operated that they shall have a computed factor of safety of at least five on the pressure carried. Some companies will not reject a risk unless the factor of safety is less than four; but I believe no boiler insuring company will carry a boiler risk when the computed safety is less than four. You probably know that the Boiler Code of the American Society of Mechanical Engineers requires that all new boilers be constructed so as to have a factor of safety of at least five.

With boiler insuring companies, a steam boiler is either safe or unsafe. If it is unsafe, there is no amount of premium that any insurance company will accept to carry the risk. If it is safe, then the premium is the same whether the safety valve be set for 225 pounds or 450 pounds per square inch, providing, as before intimated, there is a computed factor of safety of five.

Another company writes:

> We wish to advise you that the rate of insurance on a boiler carrying 300 lb. pressure or more would depend upon the amount of the liability, or, in other words, the amount required by the assured. Further, we would advise that the rates for steam boiler insurance are standardized. All companies are required to give the same amount of premium for the same amount of insurance; the amount required can be readily determined on application for a specified amount of coverage.

It would appear from the above that the companies insuring boilers would not decline to write insurance on a boiler operated at any pressure within the limits herein discussed, provided said boiler had a proper factor of safety.

If steam plants are to increase their pressure materially, the wise procedure would be to do so gradually, or in steps of moderate increases each. By this method, troubles and losses would be minimized and the experience with one installation would help solve the problems for the next increase.

The coal consumption of this country is increasing at a rapid rate, the cost of fuel is steadily rising and the total supply of good steam coal has a definite limit; therefore, it is the duty of the engineer to consider all practical methods to conserve this source of power and to utilize it in the most economical manner. Higher steam pressure will be helpful; it should be carefully studied and used wherever the conditions will permit.

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Oil Engines

Due to the industrial conditions brought about by the war, there have been few changes in the design of Diesel engines built especially for electric power plants. Correspondence with the manufacturers brings out the fact that they, like most other manufacturers, have been engaged for the past two years on Government work. With some of them this work has been along lines other than the manufacture of Diesel engines, and with others it has been in the development and manufacture of Diesel engines built especially for use in surface vessels and submarines. There can be little doubt, however, that any betterment in the construction and design which have been incorporated in the marine type will eventually be made available in the stationary type.

In our 1916 report there were incorporated certain data, including several curves, which showed the construction, operating costs and efficiencies in various sized Diesel engine electric plants. These construction and operating data with corrected unit costs may, in the main, be expected to apply at this time because of the facts outlined in the previous paragraph, making allowances for the increased cost of labor and materials.

As stated in our 1917 report, Diesel engine installations have been made in units ranging in size from 300 h.p. to 1000 h.p. and a considerable number were installed to drive electric generators. Within the past month we have been advised that one manufacturer is now in a position to supply Diesel engines for driving stationary electric generators ranging in size from 100 kw. to about 1500 kw. which is an evidence of an increasing range in available sizes.

To those who are interested in the general subject of Diesel Engines for stand-by operation, we would recommend the recently published Bureau of Mines Bulletin No. 156 entitled "The Diesel Engine—Its Fuel and Its Uses," in which the author, Mr.

Herbert Haas, discusses the recent developments in the construction of this engine, together with suitable fuels and uses to which it is particularly adapted.

Water Power Progress

There was lessened activity in hydro-electric undertakings in 1917 and 1918 and little has developed during the period in novel features of design. The difficulties incident to carrying out construction during the past two years have tended to delay the development of new power sites and to hamper the making of extensions to existing plants. Nevertheless, the demand for additional hydraulic power has had the beneficial result of drawing attention to the desirability of developing additional water power sites as soon as opportunity offers, and to the desirability of making more effective use of the power possibilities of the sites already developed. The greater importance of water power arising out of the higher production costs by steam plants may be expected to stimulate water power development. A number of propositions looking to the building of new hydro-electric plants and installation of additional units in existing plants are now coming forward.

The Hydro-electric Commission of Ontario is proceeding with a very large plant at Niagara, and the United States Government is interested in a big development at Muscle Shoals, Ala. New developments are contemplated in California, Washington, Wisconsin, New York, Maine and elsewhere.

The tendencies in design are, in general, those that were brought out in the Committee's 1917 Report. Experimenting has been going on along the lines of producing higher specific speed runners, particularly for use in low and medium head plants, to meet the growing demand for larger capacity units. The tendency is towards the use of large units with their higher efficiencies and lower first costs.

Some plant designers, for large interconnected systems, incline toward layouts of few, but large units, contending that operating and maintenance costs increase almost proportionately with the number of units, and that a few large machines can be brought back into service more quickly after disturbances, than

a larger number of small machines. The greater the number of plants that are inter-connected into one system, the less is the number of units considered necessary to be held as spare. They feel further that the reliability of modern hydraulic turbines is such that units held solely as spares would have but few useful days of service per year. This applies especially to power plants on streams of fluctuating flow, where the water power plant is tied in with large steam stations, and where maintenance work on hydraulic units may be expected to be carried on during low flow season when one or more such units would anyway be shut down for lack of water and be replaced by steam generation. During ample flow seasons, a unit instead of being carried as spare, would be used to replace steam generation.

No material advance has been made in the attainment of higher turbine efficiencies; consequently, attention has been directed towards securing minor gains in plant efficiency by decreasing the loss of head at intake and screens, and in setting, draft tube and tail race. In the draft tube particularly there seems much promise of striking improvement in efficiency. The tendency is towards the use of deeper draft tubes, with the idea of making the turn from the vertical to the horizontal direction at lower velocities than was the previous practice.

New types of draft tubes have been developed by the large water wheel builders, and data of their operating results may be expected in the near future.

From limited experimental work on inclined racks, it would appear that two benefits are to be derived, first an increased rack area, and second an automatic trash cleaning feature which requires very little manual labor, thereby insuring a minimum operating rack loss. The gain secured by decreasing the entrance losses is of great importance in low head plants.

The thrust bearing problem may be considered solved. Thrust bearings can now be obtained suitable for high speeds or heavy total loads, and they have shown themselves simple, efficient, easily cared for, and of satisfactory length of life.

Vertical shaft units are a feature of most new plant developments. There still seems to be a difference in opinion as to preference in use of direct connected exciters on the top of vertical shaft generators, as compared with the use of individual

motor generator exciters or a central excitation system. Increasing attention is being given to details of design affecting ease of operation of the turbine, and ease of conducting maintenance work on it. Accessibility of parts, better provision for thorough lubrication, removal of gate rigging mechanism from exposure to the corrosive effects of the water, provision for adjusting pinch fits of gates and taking up back lash in gate opening mechanism, are all in themselves minor factors of improvement, but of importance in the aggregate. Troubles formerly encountered from the use of oil in closed governor systems have been done away with by the use of the open reservoir system. Where water is used as an operating fluid in the governor system, the corrosion resulting therefrom and the attendant difficulties are being met in various ways at different plants; as for example: by the neutralization of the governor fluid with barium hydrate treatment combined with the use of so-called soluble oil, or by the use of potassium bichromate. The cooling of lubricating oil from thrust bearings seems to be giving some difficulty in the hot, Southern climates. It is reported that better results are obtained by using open air cooling coils on which water is sprayed and the cooling effect thus obtained by evaporation, as compared with the tank oil cooler. The insulation of thrust bearings and gear governor drives has been suggested for certain cases where stray currents may give trouble, while in other plants brushes in appropriate locations are being used to provide a path for the withdrawal of the stray currents.

The rapid rusting of intake screen equipment in corrosive river water is continuing to give trouble in certain plants, and no special sort of paint seems to have been found to afford protection for more than a few years. A very heavy red lead covering seems to be about as satisfactory a coating as any, and the expedient adopted in one plant is to withdraw and paint a certain number of rack sections each year, the cost of painting being kept down by the use of paint spray apparatus. The screens are previously cleaned by sand blast. Interest is being increasingly aroused in the development of smaller water powers consisting of low capacity, remote control plants connected together to a system using one or more plants of fairly large size as master stations.

The interconnection of water power plants with each other and with steam plants was carried out as a war measure and may be a feature of coming importance. It has brought with it a number of operating advantages and certain new and difficult problems as well. Among the features involved are the greater efficiency obtained by careful load dispatching between steam and water power plants, and the growing importance thereof; the improvement in diversity factor; the factor of insurance gained through the possibility of mutual assistance in case of equipment or other trouble in individual generating stations; the problem of governing and providing for the ready shifting of master governing from one station to another; the necessity of preventing disturbances upon one part of the system from being transferred to and felt on the remainder of the system; and the necessity of adequate protection against the increasingly severe short circuits incident to greater generating capacity on the system.

The increased demand for hydraulic power from existing plants has directed the attention of plant operators toward securing the utmost possible output from their hydraulic developments, particularly as regards increased efficiency during low water periods, and increased power output during ample flow periods. As a result, effort has been made to increase the operating head by use of flashboards and movable crest devices; to decrease losses in the tail race by deepening or rectification work; to decrease losses from leakage of water; to handle more efficiently the main units and auxiliaries during low flow, and to run all turbines during ample flow at full output, instead of at rated output, whenever in the latter case operating expedients can be adopted to take care of the electrical overload resulting.

The old problem of diverting ice from canal intakes has been attacked in a new way by Groat (see A.S.C.E. Transactions Volume LXXXII) who proposes the use of transverse sub-surface barriers to accentuate the surface velocities in a direction to carry the ice past the intake mouth, while leaving opportunity for the sub-surface flow of ice-freed water in a direction parallel to the barriers and to the intake. The use of models in matters involving hydraulic flow is receiving increasing attention and the applicability of same to quantitative and qualitative flow investigations is being better appreciated.

There is a growing realization of the importance of not only designing a hydro-electric plant for high efficiency, but of providing in its design for the necessary equipment to enable its operating efficiency to be checked up and maintained. The building in of piezometer equipment in each turbine intake is recommended in the case of new layouts; whereby, after calibration of one intake by appropriate water measuring arrangements, a continuous periodical checking up of each individual unit may be easily obtained, and thus the degree of efficiency of the hydraulic operation of the station as a whole ascertained. It is just as important in a hydro-electric plant to know the water input as to know the kilowatt output.

The Johnson type of valve is finding increasing use in water power developments, being now made in sizes as large as 144 inches in diameter, and valves of 36 inches in diameter are being used under heads of 1000 feet. A detailed description of this valve will be found in the 1913 Report of this Committee.

The committee representing the American Society of Civil Engineers, the American Institute of Electrical Engineers and The National Electric Light Association, appointed to confer with the American Society of Mechanical Engineers to draft a Hydraulic Power Plant Test Code, has had several meetings during the past year and it is expected that the Code will be in final form during this year.

Your Committee is in receipt of statements from the following manufacturers covering developments during the past year:

Allis-Chalmers Manufacturing Company

The most striking line of improvement is in connection with the capacity of the unit. Progress in this direction may be indicated by reference to the following installations which are given in chronological order:

Tallahassee Power Company, Narrows Development, Nadin, N. C., 3 units—31,000 h.p., 180 ft. head. In operation over one year at present writing.

Tallahassee Power Company, Cheoah Development, 4 units—27,000 h.p., 188 ft. head completely erected and due to start in operation this month.

Hydraulic Power Company, Niagara Falls Development (now Niagara Falls Power Company), 3 units—37,500 h.p., 214 ft. head. Erection of machinery just started.

Hydro-electric Power Commission of Ontario, Chippewa Development, 2 Units—52,500 h.p., 320 ft. head. Contract just awarded.

All of these units have approximately the same over-all dimensions and about the same size spiral casing. They are of the single runner, vertical shaft, spiral cased type, with outside operating gear, and all of them embodying a supporting barrel tying together the turbine and generator structures.

Probably the most novel improvement in connection with draft tubes is found in the hydraucone, which has been applied successfully to quite a variety of installations, where operating data are available.

This device has been installed in connection with the following plants on which operating data have become available during the past year.

Berlin Mills Company, Shelburn Plant, 2 units—1200 h.p., 17 ft. head.

Detroit Edison Company, Geddes Plant, 575 h.p., units 14 ft. head.

Manchester Traction Light and Power Company, 2 units—2175 h.p., 63 ft. head.

Sheboygan Electric Light and Power Company, 2 horizontal units—750 h.p., 19 ft. head.

Hydraulic Power Company, one unit—37.500 h.p., 214 ft. head.

In your last report we believe the direct connected type of fly-ball was indicated as being one of the recent improvements and the advantage of this style of construction arising from the elimination of all gear and belt drives, was covered in the report. The item of interest that we have to offer is in connection with the successful application of this type of fly-ball to low speed, vertical units. As an indication of the range of its adaptability as proved in practice, we would cite the following instances where it has been applied and where most of the units have been placed in successful operation:

Tennessee Power Company, 1 unit—12,000 h.p., 150 rev. per min.

Tallahassee Power Company, Cheoah Development, 3 units—27,000 h.p., 188 rev. per min.

Eastern Michigan Power Co., Foote Development, 3 units—4630 h.p., 90 rev. per min.

Aluminum Co. of America, Colton Development, 2 units—11,000 h.p., 360 rev. per min.

Hydraulic Power Company, 1 unit—37,500 h.p., 180 rev. per min.

Wm. Cramp & Sons Ship & Engine Building Co.

During the year 1918 there was considerably more activity than in the previous year, the aggregate horse power contracted for by our Company being nearly three times greater than in 1917.

One-fourth of the units contracted for by our Company during 1918

are for extensions to existing plants and the remainder for new installations.

There was a marked tendency towards the installation of high powered units, the average size per unit being 17,600 horse power. The 37,500 horse power turbines now under construction for the Niagara Falls Power Company when completed will be the most powerful turbines in the world.

For the turbines contracted for by our Company during 1918 the designed head ranges from 130 feet to 475 feet. These units are provided with cast iron or cast steel volute casings and with one exception are of the vertical shaft, single runner type. Inquiries received, however, indicate that the low and medium head installations will be developed to a large extent in the near future.

The vertical shaft, single runner unit both for low and high heads has been so thoroughly established as the best modern practice, that except in the case of extensions to existing stations already built for horizontal settings, the former type is almost universally adopted.

Pelton Water Wheel Company

First, we note a tendency to bring the water power machinery into consideration under a general heading of "Turbines." This would seem to be a proper move to simplify the classification of water power machinery generally, as, for instance, there are, properly speaking, two classes of turbines: the one, "Pelton" turbines, which are now known as "Impulse" wheels, "Water" wheels, "Tangential" wheels, etc., and the other—"Francis" turbines.

Turbines may again be classified distinctly as of the "Impulse Pelton type" and "Reaction Francis type." We are firmly of the belief that the use of this nomenclature will greatly simplify reference to either class of equipment and standardize their classification.

As to Pelton impulse turbines, the year has marked considerable progress in several ways.

First, in new developments. There is a decided tendency among the larger power companies to install units of as large a size as possible. This is of course proper under conditions where such units would form but a small portion of the total capacity of the system, and where water conditions are such that these large units can be operated practically continuously at their normal load or point of best efficiency.

Modern development and perfection in lap-welded pipes, which are now being built in this country, have to a great extent made it possible to give consideration to higher heads for the large quantities of water required in the high head power plants, and the general demand for large unit capacities has resulted accordingly. Units as large as 15,000 h.p. on a single Pelton or impulse turbine runner under heads approximating 2000 feet have been constructed.

The tendency toward the use of water economizing nozzle equipment

continues to grow, and it is apparent that, excepting in extraordinary cases, all plants of the future will provide for water storage and water economizing equipment.

Second, there is a very marked interest on the part of operators of the older and less modern Pelton impulse turbine installations to increase power outputs from their plants by installing more modern parts or details. The art has so progressed during the past few years that it is not unusual for the operators and owners of old equipments to increase their power outputs 10 or 12 per cent in this way, and at very nominal cost.

As to Francis reaction turbines, probably the most marked progress lies in the ever increasing popularity of the construction wherein the turbine runner is overhung on the end of the shaft so that but two bearings are used for the individual unit. Between these two bearings the generator is mounted, and beyond the main bearing the turbine runner is overhung. This construction has many operating advantages, as it is obvious that two bearings are always easier to maintain in alignment than three or more.

Units of this construction may be made either double overhung, *i.e.*, with a turbine runner enclosed in a spiral casing and overhung on each end of the shaft—or single overhung. The idea of overhanging the reaction turbine runners is of course a logical development, which follows a good many years of successful construction in overhanging the Pelton or impulse turbine runners. It is, in fact, rather surprising that the idea has not been more generally favored heretofore. The use of the overhung Francis or reaction turbine runner is, to be sure, not at all new, as it has been adopted in this country and in Europe for a good many years. It is, however, becoming markedly more popular of late, and we believe properly so.

End thrust is taken care of in a number of ways, most of which are already well known. The most popular type of thrust bearing is of the external mechanical construction, for the reason that its use eliminates the serious objection to water wear and difficulty of maintaining proper running conditions attending the operation of balancing devices placed inside of the turbine casing and consequently subject to the influence of the power water.

Wellman Seaver Morgan Company

At the present time we have a tremendous number of inquiries and outstanding proposals, which we expect to be settled this spring and summer. Last year was very quiet in hydro-electric work, and gave us an opportunity to carry on development work. It has been generally realized by hydraulic turbine engineers that we have nearly reached the limit on the efficiencies of runners as regards the runner itself. Ninety-two per cent and 93 per cent are about as high as can be expected. In order to show still further improvements we are looking into the

design of all passageways from the head gate to the tail race. The spiral casings, gates and draft tubes should receive special attention for each particular design of runner; this is the only way to obtain the maximum efficiency.

For low head turbines in open flume settings, we have developed an exceptionally high speed runner showing a specific speed of 170, as against about 100, which was considered the highest obtainable.

A great deal of study has been made of low capacity remote control plants, by both turbine and generator manufacturers. There are found to be a great many developments of this nature. One centrally located plant of fairly large size can be used as the master station, and several other low head plants within a radius of 15 or 20 miles can be operated from this plant without any attendants whatever except a man to drop around occasionally. This is nearly a necessary condition to make a plant of 100 to 500 h.p. a paying proposition. In order to operate these plants without attendants, it is necessary to design all machinery accordingly and make it as simple as possible. Induction generators are used in order to get around commutator troubles, and because they can easily be thrown on the line. The electrically operated gate mechanism is used instead of a governor, and gives surprisingly goods results. In case of a large load thrown off due to lightning troubles, the unit is designed so that it is safe under runaway speed. If this should happen, a man is sent to the plant to shut down the unit by hand.

We also note the increase in the number of outdoor transformer stations and the more general use of Taintor gates, both for head gates and on the dam. Several very successful installations of automatic gates, or roller dams, have been put in recently, and in one case the success of the whole proposition depended on this one feature.

The largest proposition being developed at the present time is the Niagara Development on the Canadian side, for the Hydro-electric Commission of Ontario. We have just been awarded the contract for the first two units, and the Canadian-Westinghouse Company is to make the generators. Each turbine will develop 52,500 h.p. at point of maximum efficiency, and about 60,000 h.p. at full gate. The water will be taken from above the upper rapids, through the Welland River, which will be dredged out, and thence through a canal 14 miles long by 48 feet wide and 35 feet deep, to the power house located down near Queenstown. Nearly the total drop between Lake Erie and Ontario will be obtained. The net head on the turbines will be 305 feet, the speed 187½ rev. per min., and the turbines will be single vertical and cast steel spiral casing. Ultimately it is intended to develop about one million horse power in this plant.

The large development at Muscle Shoals is being pushed by the Government, and will have about 15 units of 30,000 h.p. each under 96 feet head. There are also about five large developments in California

to be settled this spring, and three in Washington. The interesting feature out there will be the use of reaction turbines of approximately 20,000 h.p., under 800 ft. head.

Wisconsin, New York and Maine are next in line with the greatest number of active propositions. The U. S. Reclamation Service, through Secretary Lane's endeavors, will open up a great many hydro-electric developments in the west this year.

The following paper on factors in obtaining maximum output from hydro-electric plants has been submitted by Mr. Fred A. Allner, General Superintendent, Pennsylvania Water and Power Company, Baltimore, Md.

Factors in Obtaining Maximum Output from Hydro-Electric Plants

War-time demand for power was responsible for a number of improvements in the operation of existing hydro-electric plants, that can be used to advantage for after-war conditions. The features described below refer to a 100,000 h.p. low head plant, located on a river, the latter having a protracted low flow period interrupted occasionally by freshets. By means of high tension transmission lines, the plant is tied in with several steam stations of about equal total capacity. During the high flow season the water power plant operates at high load factor, running wide open for about 16 hours. The steam plants carry the peaks of the load. During the low flow season the steam plants operate at nearly 100 per cent load factor, while the water power plant carries the peaks.

High Flow Season:

When the river flow exceeds the power house draft, maximum output of the hydraulic plant is obtained by:

1. Operating main units in wide open condition for the maximum possible number of hours.

2. Adjusting gate operating mechanism in such a manner that wide open condition of operating piston actually produces maximum clear opening of guide vanes.

3. Using high flow flashboards.

4. Carrying a minimum of wattless current at the water power plant.

5. Operating a minimum of alternating current driven exci-

tation and station auxiliary apparatus during the wide open hours.

6. Improving ventilation by blowers and proper directing of air to hot parts of generators, if hydraulic output exceeds the electrical rating of some units.

7. Careful inspection and preventive maintenance of all apparatus that when out of service may reduce station output.

8. Organizing necessary low flow overhauling work so that it can be completed in a minimum of time.

Low Flow Season:

When the river flow is less than power house draft the maximum hydro-electric energy for a given river flow is obtained by:

1. Distributing total station load on smallest number of turbines consistent with load conditions, so as to cause a minimum of water draft through the power house for a given load at any time.

2. Holding forebay at highest possible elevation.

3. Efficient use of low flow flashboards.

4. Transferring wattless current to steam units and synchronous receiving apparatus, if same can be carried there at a lower overall loss

5. Distributing excitation load between water wheel and motor driven units for minimum water consumption.

6. Reducing station power requirements for auxiliaries to a minimum consistent with safety.

A number of the high and low flow features enumerated had been practiced for several years at the plant under discussion, but found a more thorough application during the war period through more stringent follow-up methods.

Some other features were introduced under war-time pressure that promise useful application in the regular operation of the plant.

1. Knowledge of the loads of the individual customers, and of the operating characteristics of those steam plants which run in parallel, is essential. Governor adjustments require to be worked out for parallel operating conditions of the various plants, so as to reduce as far as possible the number of occa-

sions when load fluctuations are taken up by the hydraulic plant instead of by the steam plants, during hours when total system load exceeds hydraulic capacity. A daily record showing the amount and specific causes of "Energy Wasted" due to hydraulic plant not being loaded up full, while steam plants carry an undue portion of the load, offers a useful follow-up method for the operating force. These losses may aggregate 50,000 kw-hr. per day (for about 2,000,000 kw-hr. total system load) and even exceed this figure, if parallel operation between the plants is not closely watched.

2. Due to the cumulative effect of lost motion in gate operating mechanism, it frequently occurs that wide open condition of operating piston does not actually produce maximum clear opening of guide vanes. Periodical checks should be made on the output of individual units and, if reductions in output are found, they should be traced to definite causes.

On a certain 10,000 kw. unit, just before the time for overhauling had arrived, this loss of output was about 250 kw., and even on units in fair condition it may easily reach 100 kw. A standard steam indicator mounted on the operating engine is useful for such investigations, as it permits the reading of lost motion in the mechanism and of operating pressure required for moving gates in different positions, etc. If guide vanes and other parts of operating mechanism were originally adjusted correctly, excessive lost motion may be compensated for by increasing the piston stroke, without taking the unit out of service. If no provision is made for this in the design, it may be possible in many cases to obtain the increased stroke by substituting a shorter piston head, which can be inserted during off-peak hours.

3. Increase of output through use of high flow flashboards may be quite appreciable. Although using boards of only about half the height of the low flow flashboards, this gain in output may, under certain conditions, equal or exceed the gain from the low flow boards.

4. For a given system load the reactive or wattless current is an undesirable element of the power load that must be furnished by the generating stations, together with the power current. In a combined steam and hydraulic system where the hydraulic plant is usually some distance away from the point of

consumption of energy, it will generally be found more economical to let the steam units and some of the synchronous receiving apparatus carry as much of the reactive current as possible. The transmission of undue wattless current through the high tension lines, step-up and step-down transformers, will increase considerably the metered reactive watts, as carried at the hydraulic station. Transmission losses will increase, and, in addition, in order to maintain normal voltage at the point of delivery, a high bus voltage will be necessary at the hydraulic plant, such higher bus voltage carrying with it greater excitation and core losses in the generators.

Installation of reactive wattmeters on the totalizing meter-bus of hydraulic and steam stations and at the points of power delivery at the receiving station is necessary for the study of such load conditions and for the "Dispatching of Reactive Load" in regular operation.

5. Hydraulic stations, that do not have a rigid system of excitation, such as individual motor generator sets or exciters directly connected to the turbine shaft, offer a certain flexibility in the distribution of excitation and station auxiliary load that may be used to advantage for obtaining maximum output. A plant with partly water wheel driven and partly alternating current motor driven exciters, and an emergency storage battery operating in parallel, should, during ample flow conditions, obtain as much of the excitation and auxiliary power as possible from the water wheel driven exciters, during the hours when the main units are operating with gates wide open. Intermittent station auxiliaries should be operated mostly during the off-peak hours, between midnight and morning peak.

6. The use of high flow flashboards or other special expedients for securing higher operating head may have the effect of increasing the hydraulic output of turbines beyond the electrical rating of the generators. The generator ratings may then be raised by providing better cooling. In such cases reliable hot spot temperature indicators are almost indispensable. If different types of generator units are used in the plant, some increased output therefrom may be obtained by running the lower rated generators at high power factor and throwing the bulk of the low power factor generation upon the units having higher rat-

ings. In some cases even this remedy is insufficient and it may pay to provide individual blowers to direct air to the hot parts of the generators, or arrange the whole plant for a central ventilating system with large blower units.

7. Careful inspection of all apparatus at regular intervals is one of the chief requirements of preventive maintenance, as contrasted with mere repairing of break-downs. This is a large field for the practical maintenance engineer in every hydro-electric plant, although it may show its value only in the course of several years.

During the hours between midnight and morning peak, and over the Sunday recess, it should be possible in many plants to carry out all the inspection work of the interior of turbines, if arrangements are worked out for proper organization of crew and for time saving inspection facilities.

8. Certain overhauling work that is necessary, due to wear of vital parts, should be completed within a minimum time, so as to keep the unit out of service as short a time as possible. Foreknowledge of the nature of the work, providing in advance the spare parts for renewal, and scheduling of the work in advance, have made it possible to reduce the time that was originally used for such work to nearly half. On several occasions a quickly approaching rain freshet in the midst of the low flow season, has been taken advantage of, by putting quickly into service a unit that was undergoing maintenance overhauling. A week's delay in each case would have entailed the loss of opportunities to utilize the flow from the freshet. In one case, for example, it meant an increase of 180,000 kw-hr. per day in delivered energy.

At the same plant a bonus system for the hydraulic maintenance force has been in use for two years, whereby the crew receives extra pay for each day that it is able to shorten the actual time that a double runner unit is out of service for major overhauling, as compared with the scheduled time.

Low Flow:

Under low flow conditions the principal aim of the hydraulic plant is to produce a maximum of kilowatt hours from a given river flow.

The joint operation of the hydraulic and steam plants under

discussion required that "best load distribution" should always be understood to mean not only best water economy, but also best combined water and fuel economy. The steam plants, during the low flow period, are operated as nearly as possible to 100 per cent load factor, using at first their most efficient units and then placing the additional and less economical equipment into service as the river flow drops lower. The problem of best combined economy is, however, largely a problem of hydraulic economy.

Occasionally it is necessary to deviate from this rule, due to temporary shortage of fuel. or to tie up of coal transportation or handling facilities at one or at both of the principal steam plants.

1. Of the eight main units of the hydraulic plant the first five have double runners of identical type, two more recent ones have runners of somewhat different characteristics, and the last unit is of a single runner high efficiency type. A table has been computed from the various turbine output-discharge curves, to assist the operators in distributing the load among the various units so as to secure best efficiency.

Theoretically the minimum total discharge from a number of turbines is obtained when the different units are loaded up to such a point on their "output-discharge" curves, that the tangents to the discharge curves at the points of loading all make the same angle with the axis of abscissae; *i.e.*, when the various units are so loaded that their "output-discharge" curve differentials are all equal.

The power house draft is plotted each hour by the operators, on the same chart on which load, head, etc., are entered. The draft for the whole day in cubic feet hours is divided into the kilowatt hours produced, the quotient being called the "Kilowatt Equivalent" for the day. From previous years' records, standards had been established for "equivalents" for the different low flow stages, with and without flashboards. A comparison of the actual daily "kilowatt equivalent" with the standard "equivalent" is used as a measure of the generating station efficiency for each low flow day. Similarly, the excitation and station auxiliary requirements are calculated in percents of line and transformer losses, etc., all of which are combined into a term called "delivered kilowatt equivalent." Such comparisons are of interest in

directing attention towards securing improvements in handling operating details.

Since systematic efforts were put forth for following up best load distribution, reduction of avoidable losses, etc., the "delivered kilowatt equivalent" of the plant under discussion was improved about 3 per cent, yielding, for example. during a certain seven weeks' low flow period, as compared with the output during a similar period before the introduction of these organized efficiency efforts, about 1,500,000 kw-hr. additional output.

2. Holding the forebay at the highest possible elevation is of considerable moment in the operation of a low head plant. This is quite apparent if it is realized that a faulty estimate of flow or load, or both, on say a fifty foot head plant, with an average connected load of over two million kw-hr. per day, but with a storage capacity of only 100,000 kw-hr. per foot draw-down of forebay pond, would entail a loss of 1 per cent of the following day's hydraulic output, if the forebay level when entering upon the morning peak is .5 foot lower than the proper level. This difference in forebay level, however, represents only 2½ per cent of the system load. It is quite apparent, therefore, that an accurate manipulation of forebay is possible only by a thorough understanding of system load conditions, foreknowledge of flow and closest cooperation with the steam plants

3. Flashboards, as a rule, are treated with less engineering care than other station apparatus that is looked upon for yielding the same amount of energy in the daily operation. Leakage between concrete sill of dam and boards, losses in the vertical and horizontal joints between boards, effect of wave action on the loosening of the tightening devices, etc., can reduce the effective gain from flashboards to a considerable extent. On the other hand, proper equipment and organization of crew for tightening the boards, erecting them quickly after a freshet, or removing them intact at the approach of a higher river stage, can increase the station output appreciably. The net gain from flashboards in the plant described, varied, of course, with the flow, but for an average low flow stage of 10,000 cubic foot second and a head of 55 feet, it could be made to exceed 60,000 kw-hr. per day.

4. Most economical distribution of a given excitation and

plant auxiliary load between water wheel driven and alternating current driven exciters is obtained by the use of output-discharge curves, just as has been explained as applying to the main units.

5. Although station auxiliaries, exclusive of excitation, consume only about 1 per cent of the high flow station output, it is possible to accomplish a measurable economy by studying the load requirements of the individual apparatus. During extreme low flow stages the above percentage may double or treble, since certain of the station auxiliaries are necessary, regardless of the amount of station energy output.

In some cases the original layout of a hydraulic plant does not provide for individual watthour meters or other instruments to measure the power requirements of the auxiliaries. Permanent watthour instruments can often be used to advantage to show the way towards possible economies in operation of station auxiliaries.

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Respectfully submitted,

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APPENDIX A

Personnel of Prime Movers Committee

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Mr. Carle: This is the first Prime Movers Committee report in two years. At the convention here a year ago I was the only member of the Prime Movers Committee present and my appointment was so recent that I had not yet attended a meeting. I was, therefore, much surprised when the Committee was appointed last September to be made its Chairman.

It was at first impossible to get the members together owing to their urgent duties at home. Then came the armistice and the Christmas holidays, and our first meeting was held in January, followed by meetings in February and March.

In January the report was divided into sixteen sub-divisions and the work assigned to sub-committees, all of which made full reports for the April meeting at which time they were reviewed in detail.

We attempted to get statements from every manufacturer of prime mover apparatus and if you fail to see any which should be in the report, it means that the sub-committee was crowded for time, or the manufacturer was unable to furnish his data in the short time allotted to him.

This is not a war report. It is a function of the Prime Movers Committee to report progress in the development of prime movers, and this report is, therefore, rather a record of what has been accomplished in spite of the war.

The Committee has a listed membership of 24, and an available working membership of 16 (15 in January). The record of attendance was:

Date	Meeting Place	Present	Possible
January	Pittsburg	13	15
February	Chicago	12	16
March	New York	15	16

I want to express my appreciation of the faithful work of the members of the Prime Movers Committee and the cooperation of the former Chairmen, Mr. Moultrop and Mr. Graves, who are members of the present Committee.

The Chairman: The report of the Committee is now open for discussion, and we will take it by parts.

We will start with Turbines, and in order to get started

promptly I will call on Mr. W. L. Abbótt, of the Commonwealth Edison Company of Chicago.

W. L. Abbott, Chicago: Among the subjects which the Committee discusses, turbines are put first as if in order of importance.

The performance of large turbines during the past two years has been a matter of great concern to companies which have used machines of 20,000 kw. and over. So important is this that it has been made the subject of study by a similar committee of another association which has devoted almost its whole time to the matter, and whose report will be forthcoming in a few months. It might, however, be permissible to say that although there have been a number of failures and serious troubles in these large sized machines—some of them coming at times to cause the greatest embarrassment and expense—there is nothing in the situation which warrants a distrust of the larger sizes, or distrust of the general features of the design of the machines of such size which have been put out. The troubles have not been confined to any one feature, but are due to a number of faults, more or less incidental, which might be expected in the development of such large machines, involving as they do new principles whose faults could be ascertained only through actual service. These faults, which have doubtless all been developed, are now in the way of being corrected.

The report gives a tabulation showing the ratios of the largest machine used by the various companies to the total capacity installed. These run all the way from 7 per cent to 100 per cent. From the fact that many companies are getting along with single units as large as 33 per cent or 50 per cent of their capacity, and not suffering seriously thereby, we may confidently contemplate the use of even larger turbines than we have been using in the past.

The Chairman: I will call on Mr. H. M. Cushing, of the Buffalo General Electric Company.

Mr. Cushing: While the Buffalo General Electric Company's steam station, from the nature of its load, cannot boast of any long continued runs of a single unit, its three

20,000 kw. turbines have been out of serviceable condition only 260 machine days in the total of 2470 machine days which have elapsed since the units were first put in service. This gives a service factor for the turbo-generators of 89½ per cent.

Most of our turbine troubles which have held a unit out of serviceable condition were due to the high temperature steam which we are using, the temperature ranging from 650 deg. to 700 deg. fahr.

THE CHAIRMAN: Is Mr. W. S. Finlay, Jr., superintendent of Motive Power of the Interborough Rapid Transit, New York City, here?

MR. FINLAY: I wish to cover my discussion of the Committee's report under two captions, as follows:

I.—THE REPORT AS A WHOLE:

I have been impressed with the fact that the report is a most valuable compilation of data and information presented as the best efforts of representative engineers and organizations. For this reason, if for no other, reports of the preceding years and those that are to come, should have been and should be correlated by presentation in a standard form. This would serve a number of purposes, primarily important among which would be:

1.—Eliminating the necessity of repeating the substance matter of previous reports, either intentionally or unintentionally, in abstract or in detail, thus, for instance, reducing considerably the bulk of the present report.

2.—Permitting indexing and facilitating the use of this and other reports for reference purposes.

Addenda could readily be made to such a standard form as occasion and the development of the art might seem to make desirable or necessary.

II.—OPERATION OF LARGE TURBINE UNITS:

Your Committee suggested that as bearing upon the desirability of installation of large turbine units, I might be in a position to report in reference to the operation of such equipment, as a result of my experience in the past few years.

In 1914 my predecessor, Mr. H. G. Stott, placed in service at the 74th Street Power Station of the Interborough Rapid

Transit Company, the first of three 30,000 kw. compound, double-element units of the Westinghouse type. As to the economic features of the operation of these machines, I reported tests upon the same before the American Society of Mechanical Engineers in 1916, the report being generally published and available, hence requiring no repetition.

As to their reliability of operation I can direct your attention to curves which I recently developed and which have been published by the Westinghouse Company in its advertising columns in the technical press.

To this equipment we have added a 60,000 kw. unit, having a maximum capacity of 70,000 kw., also of the compound type but consisting of three elements, one high and two low. This machine has now been in operation for some months and detailed descriptions of the installation have also been published.

At the 59th Street Power Station of the same company we are installing three 35,000 kw. units of the single cylinder type which are not as yet in complete operation.

You are undoubtedly familiar with the fact that the balance of the 74th Street plant is made up of a number of double, horizonal-vertical, cross-compound 7500 kw. engine generator units of the Allis type, and a single Westinghouse turbine of about the same rating.

At 59th Street there are nine engine units of approximately the same capacity, five of which exhaust into and operate in connection with vertical low pressure Curtis turbines, whose capacity is also about 7500 kw. each.

To summarize: We rate for convenience the installed turbine and engine capacity at the 74th Street Power Station as 180,000 kw. with a maximum of 190,000 kw.; the 59th Street Station, upon completion of the present turbines, at 195,000 kw. with a maximum of 210,000 kw., using as our basic unit 30,000 kw. When consideration is given to the capacity of the plants concerned, a basic unit of that particular size does not seem out of proportion nor in variance with accepted practice.

As a matter of interest, continuity of service is insured in the following manner: Spare turbine or engine capacity to the extent of 15,000 kw. is maintained floating upon the line at each plant, making a total of 30.000 kw. for the two plants. The tie-

lines between the two stations have a maximum available capacity of 30,000 kw., 15,000 of which is used for ordinary or continuous service. We are thus in a position at any time to cut out a 30,000 unit at either plant, simply falling back upon the floating spare capacity of both plants to take up the load, incidentally, it being desirable to have each plant carry its own load. It is an interesting fact that under such conditions the 15,000 floating capacity is carried without any lowering of the plant's efficiency.

As to our experience with the physical characteristics of large turbines and with particular reference to those with which we have had the longer experience, I may say that our operation of them has emphasized one particular fact, that is, that due consideration must be given to operating refinements, but when given, such operation becomes routine, only differing in its character from that in connection with the old engine-driven equipment. (Applause.)

The Chairman: These expressions of opinion should study not only the engineering end, but should also take in the operating end. To speak on this point we will now ask Mr. Philip Torchio of New York City to say a few words.

Philip Torchio: I endorse what Mr. Finlay and Mr. Abbott said regarding the situation of the large turbo units. I would add, however, a few words in regard to the impression which some people have that there is a definite limit of size of single shaft units, variably put between 20,000 and 40,000 kw. which cannot be exceeded with safety. This is not true. In fact, there is no limit to the size, provided you lower the speed, so that a 90,000 or 100,000 kw. unit is perfectly feasible. Other considerations, foreign to the question of safety, may make these large units undesirable. In the case of the troubles experienced, it may be that to some extent they have been due to the fact that for that special speed manufacturers tried to extract a little too much power, but had they taken a lower speed design they could safely have made the machine considerably larger. It is true that some designs do not lend themselves to the construction of immense wheels for large low speed machines, but other designs may be used for larger machines, if needed. In other words,

we must not be carried away by the misconception due to some few failures to curb the progress of the art. I repeat that we may not want a 100,000 kw. single shaft unit, as there are only one or two stations that could use it to advantage, but that is another consideration.

As Chairman of the Power Stations Committee of the American Institute of Electrical Engineers, I take this occasion to notify you that I have secured the cooperation of two prominent manufacturing engineers to prepare engineering papers in relation to the possibilities of design and size for practical studies of single shaft units. I expect these papers will be presented at the November meeting of the American Institute of Electrical Engineers, and I hope that all those interested in this subject will participate in the discussion and take part in the meeting.

THE CHAIRMAN: I see Mr. Junggren of the General Electric Company. Will you come forward, Mr. Junggren, and say a few words?

O. JUNGGREN, Schenectady, N. Y.: Gentlemen, in making statements in connection with large turbines I could not make a statement any clearer or more to the point than has been made by the General Electric Company in this report.

You all know the difficulties which everyone faced during the war, and also during the period preceding the war. You know how difficult it was to obtain suitable material; also what everyone had to contend with in connection with work in the engineering division, the drafting, and the work of actual labor.

A contributing cause of the trouble which occurred to some of our turbines was the tremendous program to make machinery for the Navy, and also for the Emergency Fleet Corporation. The volume of business practically doubled during the period of the war, and it was necessary to utilize the personnel of all the various departments in order to carry out the program. I think the General Electric Company carried out this program very well, and it actually did furnish a large amount of durable machinery for the ships which were built.

Our turbine business suffered in all its branches, and what-

ever mistakes or difficulties you encountered were due not only to defects and difficulties of materials and workmanship but to the condition under which all branches had to work.

To show you the progress that was made in the manufacture of ship machinery, I want to mention one item and that is that the Company is now shipping out complete destroyer turbines that will not see the hulls they are to go in for two years to come.

There is no reason for apprehension that we will not be able to carry out our obligations on the turbines that we have begun. We are now using all our facilities to correct as promptly as possible the difficulties we have had. I fully realize that some of you gentlemen think this work should go faster than it is going. There is no reason to doubt that the turbines will be as reliable and give as good continuity of service as any station may require. (Applause.)

THE CHAIRMAN: We would like to hear from Mr. Sniffen of the Westinghouse Machine Company.

E. H. SNIFFEN, Pittsburgh: I have only a few words to say on this subject.

I think that problems embraced in the design of steam turbines are as important as those in any branch of engineering with which we have to deal. I think there can be no doubt of that. The situation has been that from the beginning of the turbine business, something like eighteen or nineteen years ago, the engineering enterprise involved in the designing of steam turbines has been left largely to the manufacturers themselves. I think there is nothing more creditable in the annals of the engineering profession in this country than the progress which the turbine manufacturers have made in bringing forward these large prime movers, upon which the electrical industry has so much depended. But I look forward to the time when we shall see greater cooperation between us all. I think it is a good thing that different types of turbines have been built by the different manufacturers, representing different schools of thought. Now that the manufacturers have evolved their designs to a very full degree, so that we are all pretty well acquainted with the possibility of the various types, I believe the thing we should

strive for is a little more of the standardization and cooperation of thought that we find in electrical apparatus. I think there is no good economic reason to justify such wide departures in practice. We have had 20 years of experience, so why cannot we get closer together as we have done under the jurisdiction of the American Institute of Electrical Engineers, and as we have done in the National Electric Light Association?

I do not think there should be so much diversity of opinion and I believe the development to be looked forward to will be the result of a greater degree of interchange of opinion between the manufacturers and the engineers who have to live with these machines, and who must have some ideas about them.

It is generally considered that the satisfactory operation of a large turbine depends upon the details of design, and I must say very frankly I think the manufacturer has been too long permitted to evolve his ideas without more insistent cooperation on the part of the operating people. So, speaking from the manufacturing standpoint, I think we would all welcome a greater degree of interest in these machines than we have had. Meanwhile we will build them the best we know how. (Applause.)

THE CHAIRMAN: We have not much time left for general discussion on the turbine problem, and we would like to hear from a few of our members at least. Does anyone desire to discuss this question?

H. B. BRYANS, Norristown, Pa.: We recently started a 5000 kw. unit at our plant in Norristown, and I was surprised to find that the manufacturer insisted upon having the point at which the automatic speed trip out will operate 5 per cent above normal. I find that 5 per cent above normal is not sufficient to take care of surges and changes of speed which take place in short circuits. Has the Committee considered that problem, and if so, to what conclusion did it arrive?

THE CHAIRMAN: Any one else? We will not answer detailed questions now. We will make a note of them, and have the Committee answer you direct. That is more a generator than a prime mover problem.

We will proceed to the next subject on the program, "Higher Steam Pressures," and I will ask Mr. Richard Rice, of the General Electric Company of Lynn, Mass., to open the discussion.

Mr. Rice: Mr. Chairman and Gentlemen, I have been much interested for some time past in the question of the utilization of higher steam pressures for turbines, since it is one of the obvious and, I believe, one of the practical methods of extending the range of available energy which can be derived from the fuel which we burn under our boilers. I believe that the additional available energy thus put at our disposal can be utilized to increase the output of current from that fuel; in other words, increased output without increase of fuel consumption.

This is one of several methods now available by which we can increase the output from our fuel. Another of these methods is by increasing the vacuum at the last turbine wheel. This may be done by improved methods of arranging the tubes in our surface condensers so that a larger area of tube surface for condensation may be presented to the entering steam, and by bolting the condenser directly to the wheel casing with the largest possible area of opening to the condenser.

Another method of increasing output is by extracting heat from the waste gases so that these gases will go up the stack at a temperature of 125 to 150 degrees fahr., instead of 400 degrees to 500 degrees, as is common in our best plants. This may be done by additional feed water heating provisions at a reasonable expense, and the gain realized is considerable.

The importance of all these matters would be shown if your Committee would consider the performance of plants with reference to the thermal efficiency instead of with reference to Rankine efficiency. In other words, the measure should be percentage of power developed from the available energy in the coal and delivered to the switchboard.

The best plants today give a thermal efficiency of 18 per cent to 19 per cent, whereas by attending to the points above mentioned and using steam at a pressure of 500 pounds per square inch, you can arrive at a thermal efficiency of 25 per cent for plants of very reasonable size, and in large plants this

thermal efficiency can be raised to 28 per cent or 29 per cent, which is a gain well worth striving for.

Before utilizing steam commercially at 500 pounds pressure, it will be necessary to acquire some experience, which experience can best be gained by building a plant containing units of 2,000 to 3,000 kw. capacity; and this plant will be a thoroughly commercial proposition as soon as it has been operated long enough to develop the small difficulties which are likely to arise in making a substantial increase in steam pressure of this nature. After this point has been reached, it will be wise to proceed to the construction of a plant with large units.

The step upwards to 500 pounds pressure is fully warranted by the experience which has been obtained with plants where the steam pressure is 300 to 350 pounds.

In designing plants to be operated at this high pressure, it seems to me that a different arrangement of units would be desirable so that the steam pipe may be made of minimum length. In other words, the steam turbine should be located as close as possible to the boiler.

THE CHAIRMAN: Is Mr. A. L. Meyer, of the Lukens Steel Company, of Coatesville, Pa., in the room?

MR. MEYER: As far as I am able to read this report, all the manufacturers who would make up apparatus to give higher steam pressures seem to point to the boiler as the object of which they want to make certain. Except for the few plants herein reported as using higher steam pressures, I have not been able to find any actual boiler test in which this subject has been covered.

But from the steel maker's point of view we feel entirely confident that the use of the present standard low carbon steel of 50,000 to 60,000 tensile strength per square inch will give those qualities necessary for boilers which are to stand the higher steam pressures.

Experiments performed on the physical qualities of this low carbon boiler steel point to the fact that up to a temperature of approximately 700 deg. fahr. the tensile strength of that steel, and likewise its elastic limit, remains equal to 100 per cent of its original or better. In other words when the temperature

exceeded 700 deg. fahr., the curve depicting the physical properties dropped abruptly and showed qualities which are not to be trusted. Examination of the chart in the Report shows that point very clearly. This chart is taken as representative of the different classes of steel mentioned for boiler work and the experiments were performed by Dr. Huston, Lukens Iron and Steel Co., in 1878; and by J. E. Howard, Watertown Arsenal, Mr. Coleman of Oberhurst University and the Shelby Steel Tube Company at a much more recent date. The work of each of the experimenters corroborates the pioneer work of Dr. Huston.

The contents of the letter from Mr. C. L. Huston, vice-president Lukens Steel Company, reprinted in the Report is a very able discussion of this subject and is self-explanatory with regard to the reason of the weakening of these steels above a temperature of 700 deg. fahr.

In England, in the manufacture of Scotch Marine Boilers, they use steel which has a minimum tensile strength of 74,000 pounds, which might cause some consideration from the point of its strength, but from the viewpoint of higher carbon contents necessary to make this strength and the uncertain condition of segregation, which must necessarily increase with increased carbon contents, this steel is not suggested. Therefore, the standard low carbon steel of a 50,000 to 60,000 pounds tensile strength, with segregation at a minimum is the proper steel to use for boilers in which higher steam pressures are made.

Should greater strength be required in the plates making up these boilers, it is the most fitting suggestion that this strength be made up in actual thickness of the plate and that the present low carbon boiler steels still remain as standard.

THE CHAIRMAN: Does anyone else wish to say something on the higher steam pressures? I am sure someone else in the room has dreamed about this day of higher steam pressures; we do not care whether it is for or against.

I. E. MOULTROP, Boston: Mr. Chairman and gentlemen, the subject of higher steam pressure or temperature for steam prime movers is something which we have all considered very

carefully. There is no argument against it from the thermodynamic standpoint and it remains for somebody to work it out. The chief limitation today seems to be in the material to be used for and the design of the boiler. Present boiler designs limit the pressure to about 350 pounds, and to go higher requires an entirely new design, which apparently the boiler manufacturers do not desire to attempt until there is a sufficient demand for it. While there is a definite temperature limit imposed by the commercial steels, I think this limit is sufficiently high to enable us to go a long ways towards utilizing the advantages of higher pressures. I believe the next step is for some one actually to build a small plant of say 3000 to 5000 kilowatt capacity, going to the maximum temperature and pressure that the commercial materials will allow; that is, probably around 700 deg. fahr., and this would probably mean a boiler pressure of around 500 with moderate superheat. This is an expensive undertaking, and I think that none of the utility companies today would care to undertake it.

I believe that if the member companies of this Association asked the principal manufacturers of boilers, turbines and auxiliaries to combine on the construction of such a plant, a way could be found to put through this project without imposing an unreasonable financial burden on any one company. I strongly recommend that some such action be taken. An experimental plant of this kind can be built somewhere in this country where its output can be used commercially and such a development would be a great help to the industry.

With the rising prices of fuel and labor it is imperative that some methods be found whereby the cost of producing electric energy is not only kept within present limits, but materially reduced, and there is no question but a greater economy can be shown by going to higher steam pressures than by any other expedient which has been considered within recent years.

THE CHAIRMAN: Has any one else anything to say? If not, we will proceed to the next topic—Boilers and Superheaters. I have asked Mr. P. C. Idell, of The Babcock & Wilcox Company, to open the discussion.

P. C. IDELL, New York: Mr. Chairman and Gentlemen,

Your committee has gone into this very thoroughly and has covered the main points in boiler practice today, and if you would ask me for a short concise discussion on the subject, I would approve it as written.

Looking at it in detail, and taking the topics in the order mentioned, considerable improvement has been made in the design of furnace walls and materials used in their construction, but, for long life, we would like to emphasize the need of avoiding pressure above the fire.

Aside from the erosion caused by blow-pipe action, most of the rapid deterioration of furnace walls is caused by carrying a pressure or nearly neutral draft above the furnace bed when operating the boilers in response to emergencies or peak loads. At least 0.10 draft should be carried over the furnace bed at all times.

We have been interested in several designs of patented baffles that are now on the market but until these are more nearly perfected we are still recommending our own design.

Some means of ventilation should be provided in the back and side walls and, I should like to add, in the front wall also, as that is where most of this trouble starts.

We are now cooperating with the stoker companies and this cooperation, with the benefit of your experience, is helping us in designing a construction that will be more durable.

The introduction of a small amount of air, through properly located and proportioned air inlets in the side, front and rear walls of the furnace, at or near the top of the fuel bed, has resulted in a material decrease in repairs and consequent prolongation of the life of furnace walls, without any noticeable effect on the efficiency.

Boiler Forcing Rates

We agree with the Committee that there has been a reaction in the maximum outputs, and this is very clearly stated where the Committee suggests you must take into consideration the ratio of heating surface to grate surface.

It is easy to lose sight of the fact that furnace conditions incidental to the operation of the boiler at 400 per cent of its normal rating, where the rate of heating surface to grate sur-

face is 30 to 1, are very different from the furnace conditions when operating at 400 per cent of its rating, a boiler, the heating surface of which is about 75 times the area of the grate. The decision as to the best amount of heating surface to be used is a problem, in each case depending upon the kind of fuel, its heating value, its burning characteristics and variation in the output required from the unit. Maximum overload capacity of 300 per cent might be better practiced in one station than 200 or even 150 per cent maximum overload capacity in another.

I am pleased to note the careful way in which your Committee has called attention to loss of draft through the boiler at various ratings. It is very important to realize this loss. Also, this loss is a direct factor of the volume of the products of combustion and will occur at high ratings with good combustion and, also, at low ratings where there is a large amount of excess air.

A series of exhaustive experiments with various kinds and makes of tubes has demonstrated pretty clearly that if it is kept clean inside and outside, little trouble will be experienced with any boiler tube. A steam boiler is a concentrator of the mixture of water and other things which it receives from the feed pump, and it is expected to deliver only pure water vapor. The harder a boiler is driven, the more rapidly it concentrates, so that the purification and treatment of feed water have become a much more important factor of plant operation than before high rates of fuel combustion were considered good practice. A certain amount of concentration seems to be necessary, and the consequence of too much of it is so serious, under the present operating conditions, that constant vigilance and tests of the water contents of a boiler are necessary, and an ever present operating problem.

Assuming the interior of the boiler tubes to be kept nearly free from scale or other non-conducting material, and assuming the exterior of the tubes protected from blow-pipe action and sufficiently removed from the intense radiant heat of the fuel bed, it is true that the limit to the steam generating capacity of any well designed boiler is the limit to the amount of fuel which can be burned in the furnace. The higher the rate of heating surface to the grate surface, the greater the care to be taken

with regard to the disposition of boiler heating surface with relation to fuel and furnace conditions.

Cleaning External Heating Surface

Experience with mechanical soot blowers is being followed by improvements in their design and location, which seem to make them a necessity in every well designed power plant.

Feed Water Regulators

We believe in feed water regulators, but not to the extent that you omit constant visual attention.

Superheaters

The superheater is not fitted to an inflexible design of boiler. Before we offer a superheater we ask for your service conditions and then consider the proper width, height and length of boiler for this service. At the same time we select the proper design of superheater, and the boiler and superheater are studied as a unit to give you the proper pressure and temperature of steam throughout your range of operating conditions.

Coating Exterior Surfaces of Settings

I have seen a number of these preparations in service and reports are in their favor. I might make a suggestion—that while a thin coat may be enough to answer the purpose from a standpoint of boiler efficiency, a thicker coat, applied more as a wall plaster, would improve the appearance of the setting.

The Chairman: Is Mr. Robert Wyld of the Power Specialty Company here?

Robert Wyld, New York City. Mr. Chairman and Gentlemen, In regard to the superheater matter, the report covers the main subject very fully, but there are a few points that I thought it might be of interest to bring out. A very important point is the condition under which the superheater has to operate in relation to the boiler. It is very necessary that the condition of the steam shall be proper to give the best results in the superheater. Moisture is not good when supplied to a superheater in excess. The superheater is designed to superheat steam and not to evaporate water.

Then another point is the question of properly cleaning the superheater; and in that connection I think the superheater should be considered as a good indicator of conditions in the boiler. If solid matter is carried into the superheater with the steam, that will have a bad effect on the superheater and its operation, decreasing efficiency and eventually causing failure if not attended to. Keeping the superheater clean on its outside surface is also necessary to give the best results. The superheater cleaning on the inside should be done away with by getting at the trouble at its source, thus getting rid of the trouble before it gets to the superheater. Superheaters can be washed free from any sediment that is carried over by the steam. To keep the outside surfaces clean, permanent soot blowers are desirable so as to get the best obtainable efficiency from the superheater proper.

One of the Committee members stated to me that the question of superheater design was of interest to many members— Mr. Primrose, our chief engineer, is here, and I would like to have you hear from him on superheater specifications. This idea of using a proper superheater specification is of much value.

THE CHAIRMAN: We will be very glad to hear from Mr. Primrose.

JOHN PRIMROSE, New York City: Mr. Idell and Mr. Wyld have called attention to interesting points, and I should like to emphasize Mr. Idell's suggestion of the need for more complete superheater specifications. The performance of the superheater is influenced very largely by the kind of fuel, method of burning and the evaporation per square foot of boiler heating surface, and these should all be specified, as well as the usual steam pressure, to enable the proper proportion and arrangement of heating surface to be selected.

The report of your Committee mentioned the restricted space usually provided by the boiler builder for superheaters, but of late better cooperation between the boiler and superheater builders is correcting this condition, so that more desirable superheater arrangements can be worked out, making the superheater surface more effective. This makes the higher temperatures called for by recent practice entirely possible.

For extremely high temperatures or where some types of boilers are used, a separately fired superheater may be desirable. A new design recently put into operation demonstrates that such superheaters can be operated at an efficiency at least as good as the boiler efficiency. The difficulty heretofore has been that high furnace temperatures could not be carried without damage to the heating surface. This has been overcome by providing elements of special construction directly over the furnace—sometimes forming the stoker arch—and these elements reduce the temperature of gases entering the usual heating surface by the amount of radiant heat absorbed. In this way high furnace temperatures are safely carried and the gases cooled to within a few degrees of the temperature of the entering stream.

DAVID B. RUSHMORE, Schenectady, N. Y.: In connection with the discussion of the use of higher steam pressures, it would be of interest to obtain the results of work done at Cornell University in the years 1894, 1895, and 1896 with pressures ranging, as I remember, from 600 to 800 pounds. This steam was generated in a specially designed boiler and was utilized in a quadruple expansion engine. The descripton of the apparatus and machinery used and the results of the test must be on file at Cornell.

O. JUNGGREN, Schenectady, N. Y.: It is indeed a vital question to consider higher steam pressures. We are reaching out continuously for improvements, and as long as we use steam as a medium we must ascertain how we can utilize steam to best advantage. We can go into only the upper range, as the lower range, which is dependent on temperatures of condensing water, has practically been reached. One way is to use superheated steam, bringing it to a temperature as high as it is practical and feasible to go, but that is not the real thing. The pressure should be increased, at the same time keeping the temperature as high as is practical with the higher pressure, as the higher the pressure you go to the more steam you are transforming into water in the turbine. If we could transform all the steam into water in the turbine and get rid of the condenser we would have the ideal condition. We do not know how to do this and,

therefore, every per cent of reduction in the quantity of steam that is sent to the condenser is a clear gain.

We consider it feasible to design turbines—at first for moderate sizes for pressures of 600 or 800 pounds or even higher. Of course, there will be problems in the boiler as well as in the turbine and auxiliaries that have to be overcome when operating under pressures as high as 800 pounds. But, in my opinion, real economy is to be realized from increase in pressure, and not from increase in temperature.

THE CHAIRMAN: All these questions are inter-related. The main part of the problem is the production of boilers for the production of these higher pressures. Is there anything else to be said on this subject? (No response.)

"Economizers" is next. We will ask Mr. Herlan of the B. F. Sturtevant Company to open the discussion on Economizers.

F. HERLAN, Hyde Park, Boston, Mass.: Mr. Chairman and gentlemen, the Committee's report on economizers is so complete that it leaves me very little to say.

The question of higher steam pressures is of interest to us as well as to yourselves and for some three years we have been making investigations along these lines. The present high pressure economizer is suitable for 350 pounds to 400 pounds. There is a table in the report in which we show the ultimate strength in pounds per square inch of the various parts of our economizer, and you will find the smallest factor of safety to be 18 to 1 at 400 pounds pressure. Of course this is based on the assumption that the material is not defective.

We are now conducting experiments, the nature of which I cannot disclose, which, if successful, will materially strengthen our economizers, will increase the transmission rates and improve the operation of the scrapers. It may take us a year or two to work out these experiments, but if they are a success there will be a great improvement in present economizer construction.

The mention of scrapers reminds me that, in my reply to the Prime Movers Committee's question regarding cleaning, I referred to the inside of the tubes, and it occurs to me that pos-

sibly some mention was desired of external cleaning. I want to endorse most emphatically what the Green Fuel Economizer Company has said. We all admit that the scraper mechanism is the weakest part of the economizer, although we have also found that 80 per cent of the troubles encountered are due to inattention on the part of the operators. If scrapers were given a little more attention, a large majority of the troubles would be eliminated.

In regard to the pitting of tubes, with certain plants burning a coal containing high percentage of sulphur and moisture, the gas contains a large relative quantity of sulphurous acid which attacks the tubes, particularly on the cold end of the machine where the moisture begins to condense. We have tried painting the tubes, but with very little satisfaction. The Illinois Light & Traction Company recently drew our attention to a product known as Gummite, which is acid proof and is supposed to set like a cement. I know nothing of this, but suggested that the Illinois Company try it out.

We are also trying some experiments in Chicago where high sulphur Illinois coal is used, coating the interior parts of the economizer with solution of silica, also a lead alloy. We also intend to try a harder grade of iron, although this will not apply to the pipes or headers.

We have also been experimenting with water circulation. The old method of natural circulation, where the water came in at the bottom, rose through all of the tubes and was taken off at the top, has been practically abandoned and modern economizer installations are arranged for forced circulation, usually with three to five passes. At the present time we are changing over one machine to give single section circulation, that is to say, the water will rise up one section and down the next throughout the machine. While this may give better transmission, we are inclined to believe that the loss of pressure in getting the water through will more than offset the gain in transmission.

THE CHAIRMAN: Is Mr. C. S. Messler of the Green Fuel Economizer Company here?

C. S. MESSLER, New York: Mr. Chairman and gentlemen:

This subject of economizers has been so well covered in this report, and also in the statements which the manufacturers have made, that there is very little I can add.

I think you will all admit that to get the higher efficiencies of the boiler plants which you desire, it will be necessary to have an economizer in the equipment. There seems to be a question as to whether or not the economizers will operate under the high pressures. There is a table in the report which shows that the economizers have been installed on pressures up to 350 pounds, and are operating satisfactorily. I think they could be designed for even higher pressures. But I think it is not necessary to put an economizer under higher pressure as the temperature of steam at 200 pounds or 250 pounds pressure will give you practically all differences of temperature you need in a central station. So it will be possible to operate your economizer under present conditions of pressure, and still recover all the heat from your gases that it is possible to recover.

I do not think there are any other points which have not been covered, which I could take up now, unless someone has a particular question to ask me. (Applause.)

THE CHAIRMAN: We have heard from several of the manufacturers on this question of economizers. We would like to hear something pertinent from a user. I should like to have heard of a possible reduction in the cost of economizers. I know of several instances in which economizers were discussed for installation in plants, and as soon as bids for them were received, the discussion was discontinued.

Is there anything further on this subject?

The next question will be Stokers and Grates, and I will ask Mr. H. M. Cushing, of the Buffalo General Electric Company, to open this discussion.

MR. CUSHING: The Buffalo General Electric Company, on account of its large stoker capacity, was able to carry from 300 to 350 per cent rating on its boilers, even with the poor coal received under war conditions.

We now operate eleven 1140 h.p. double fired Babcock & Wilcox boilers, ten being equipped with two 15-retort Riley Stokers, and one with two 12-retort Westinghouse Stokers.

Both types of equipments have been operated up to 500 per cent of boiler rating.

THE CHAIRMAN: Mr. C. B. Grady, of The New York Edison Company.

MR. GRADY: Referring to coal storage and coal handling and to the prevention of heating and deterioration of coal, I would like to bring out a few additional features of the coal handling equipment at the U. S. Government Explosives Plant, Nitro, West Virginia, which has been briefly described and illustrated on Pages 109 and 110.

Each boiler house contains seventeen 1043 h.p. water tube boilers, making a total of over 35,000 b.h.p., the maximum coal consumption being about 3,000 tons of coal per day. Boilers are equipped with underfeed stokers.

The entire coal handling equipment for the plant consists of 3 locomotive cranes—2 in use and 1 spare—and 2 movable crusher cars equipped with duplicate crushers, each of which is large enough to handle the required amount of coal.

In view of the simplicity and reliability of this equipment, it was considered safe to carry only a small amount of crushed coal in the bunkers, the total coal on hand (60,000 tons) being divided as follows:

54,000 tons of run-of-mine coal adjacent to and between the boiler houses;

6,000 tons of crushed coal (two days' supply) in small overhead bunkers in front of and above the boilers.

If a fire should start in the outdoor storage, the coal could be shifted by the locomotive cranes. If there is a tendency to heat in the lower part of the bunkers containing crushed coal, no inconvenience will be encountered as the coal will run down into the boiler furnaces in a few hours.

THE CHAIRMAN: We would like to hear from Mr. T. A. Marsh, of the Green Engineering Company, Chicago.

MR. MARSH: Much of importance has been written about clinker removal. The paragraph on page 82 relative to ash and clinker removal is interesting. Stokers of the "K" or "L" type are particularly adapted to high ash coals or to coals whose ash

fuses at a low temperature (that is, clinkering coals), also to the low ash coking coals of the East. Green Chain Grates and "L" type stokers remove the ash continuously from the furnace, so that there is no clinker formation or periodic dumps. Coals containing 30 to 35 per cent ash are being burned regularly and continuously on these stokers with low attendant labor and with no clinker trouble. During the past year, although we had over one and one-half million horse power in service, we have no record of shutdowns, due to clinker trouble, in any of the plants served by our stokers. Single stoker units up to fifteen feet wide are built so that single stokers can be adapted to serve boilers up to one thousand rated horse power. No steam jets are used along the sides or the bridgewalls to prevent clinker adhesion, and the steam to drive even the largest unit is less than thirty pounds per hour. All efficiencies and capacities obtained are, therefore, net results—not subject to any deductions for auxiliaries, clinker prevention and clinker removal.

We do not have any specific apparatus for clinker removal as that is one of the primary functions of chain grates.

I would call attention to the necessity of larger furnaces. We must have larger furnaces if we are to improve the combined efficiency of boilers and furnaces. I know of only one-half dozen plants in the country which have large enough furnaces to reduce the hydro-carbon losses to a proper minimum. We now consider furnaces having twelve cubic feet for each square foot of grate as large furnaces. We must come to furnaces of larger volume, fifteen or even twenty cubic feet per square foot of grate.

E. B. Ricketts, New York City: In forced draft stoker installations it has been my experience that the most efficient results are obtained when all of the boilers in service are being operated at the same rate; this condition can be most easily maintained by supplying all of the boilers from one air duct provided with fans at appropriate intervals controlled from one central point. This central control of air pressure can be obtained either by automatic regulation from the steam pressure or by hand regulation. Where the boiler plant is of sufficient size to justify one man spending most of his time regulating

steam pressure, I believe that intelligent hand control is better than automatic because (1) automatic devices get out of order; (2) with hand control the steam can be regulated with much smaller fluctuations in air pressure and consequently more regular boiler output; (3) with hand control the regulator, knowing when to expect the peak load, can bring the steam pressure up to just under the blow-off point at the time when the peak is to be expected, thereby gaining four or five pounds over the pressure which is usually carried. This good start helps materially in carrying a short heavy peak.

Regarding the tendency to sectionalize the stoker drive on underfeed stokers, attention might be called to the ease with which this is accomplished in stokers, using a steam cylinder to actuate the rams such as the Type "E" and the new Jones. These stokers offer a very simple means for controlling the stroke on each individual ram.

JOHN DALLAS, Philadelphia: In the paper as presented, reference is made to the use of waterbacks in connection with boilers and stokers and the location of these waterbacks in the bridgewall. I would like to give a report of the experience of The Philadelphia Electric Company relative to the use of cast-iron waterbacks in the bridgewall of 1500 h.p. single fired class M Stirling boilers, designed and operated by our company.

We wish to emphasize the fact that even if clinker grinders are set quite deep below the fuel bed and the approach to the clinker grinders is sufficiently wide, trouble may be expected by the clinkers arching over at a deeper point in the pit unless proper provisions are made to prevent this occurrence. The Philadelphia Electric Company has had considerable experience in the operation of these clinker grinders and has adapted waterbacks as a means of preventing this trouble. If waterbacks are properly designed, connected and operated, the troubles experienced by arching over the clinker grinders can be practically eliminated and the heat which is absorbed through the waterbacks can be utilized without any loss.

Two boilers were installed in 1917 by the Philadelphia Electric Company and have been in operation for a period of about a year and a half, during which time it has not been necessary

to replace any of the waterbacks. In this particular instance, all of the boiler feed water for the two boilers was passed through the waterbacks and into the open feed water heater, thus saving all of the heat absorbed through the waterbacks.

The first waterbacks as designed by The Philadelphia Electric Company, were of an oval section 6 inch by 12 inch outside and 4 feet 6 inches long. These particular waterbacks had from 2½ to 3 feet of the total length exposed to the direct heat in the furnace and the water passing through this type of waterbacks absorbed 4½ to 5 per cent of the total heat generated in the furnace. We have since changed the design of these waterbacks by shortening them to 3 feet in length. This has cut down the total heat absorbed through the waterbacks to from 1¾ to 2 per cent maximum. While the length of the waterbacks has been reduced by about only 33 per cent, the heat absorbed through the waterbacks has been reduced by about 60 per cent. This can be explained by the fact that in the long waterback almost one-half of the total length is exposed to the direct heat of the furnace; whereas, in the short waterbacks, only about one-sixth of the length is exposed to this heat; the balance of the waterbacks being below the top of the fuel bed where the heat would be considerably less than in the open furnace.

In our Chester Station, where we have eight single-fired Stirling boilers with Taylor stokers and clinker grinders, our waterbacks are erected at the bottom of the bridge wall sloping inward at an angle of about 8 degrees and are connected parallel to an inlet and a discharge header. These headers are placed at the back of the bridge wall and the pipes connecting the headers to the waterbacks are provided with flanged unions so that any waterback section can be withdrawn without disturbing the bridge wall construction. The inlet header is at the bottom of the waterbacks.

There are two main water supplies to the waterbacks, one of which carries condensate water from the condensers, the other carrying raw water, which is for emergency use. The supply to each boiler is taken from either of these mains through a specially designed valve which ordinarily is set to allow condensate water to run through the waterbacks and return through

the same valve to the plant feed water heater. By one operation of this valve, the condensate water is closed off and raw water is supplied to the waterbacks and returned through the same valve to waste. In order to give protection against a failure of condensate water supply to these waterbacks, there is a temperature alarm on each discharge header which is set at 160 deg. fahr. so that if the water supply is too small, the temperature will rise and cause this alarm to ring, at which time the boiler engineer can throw over the supply from condensate to raw water. As an additional precaution against burning out these waterbacks in case of a sudden shutting down of the turbines, there is a stand pipe with a regulating valve on the condensate main. This regulating valve is set at such a point that if the condensate water supply fails, raw water will be run in through the same main.

In this installation, all of the heat which is absorbed through the waterbacks is saved and returned in the condensate water to the feed water heater. By using only the condensate water from the condensers in all of the boilers operating under whatever load is being carried, the discharge temperature from the waterbacks does not exceed 145 degrees fahr. with 101 degrees fahr. condensate water, when carrying 28 inches of vacuum in the condenser. When carrying 29 inches of vacuum, the discharge temperature from the waterbacks will not exceed 125 degrees fahr.

The results obtained by this installation have been so satisfactory that we have no hesitancy in recommending this type of installation for all single-fired boiler settings where clinker grinders are used in connection with the stokers, and we believe that such an installation would be advantageous in any type of single-fired boiler setting with stokers.

THE CHAIRMAN: Is there anyone else with anything to say on Stokers? If not, we will proceed to the next question, Pulverized Fuel.

I should like to say a few words on that subject myself. Recently I visited in Seattle the plant of the Seattle & Puget Sound Electric Company, where an installation for burning powdered fuel has been under consideration and operation for

some months. This is a pioneer installation and the Company has spent a good deal of money, like all pioneers. The big point is that the feasibility and economy of burning pulverized fuel were fully proved.

In Seattle powdered fuel is supplied to 4 or 5 installations in the city,—apartment houses and office buildings, hotels, etc. It is shipped in closed tank cars, and delivered in closed tank wagons, and it runs from the wagon by gravity into the customer's receptacles. The principal difficulty comes in the grinding and powdering, which operation is not standardized. There are several schools with different types of materials and grinders, and as to this point anyone going into the situation will have to be careful. That is where a big part of the money is spent. I have to attend another meeting and I have asked Mr. Carle to take charge of this session.

(Chairman McClelland turns the gavel over to Mr. Carle.)

A. D. Bailey, Chicago: Before the last speaker leaves, I would like to ask what the charge is where the local company does it?

Mr. McClelland: They are delivering at $7 a ton, but it is about $1.50 a ton for preparation. They are using what we call culm fuel. At the coal mines, where these pulverizers are located, they had a fuel with a high percentage of slate and earth. The Seattle people were getting unwashed fuel from these mines. That is one of the difficulties in burning the powder in a city—the infinitely fine ash or dust from it settles all over the surrounding district. They are installing a smoke washer.

Chairman Carle: They are using anthracite. For apartment houses I understand a company has been organized in New York, which will deliver it in containers properly prepared for burning. The development is being held up somewhat by the fact that nobody furnishes all of the apparatus and all of the engineering, although some are starting to. The situation should be taken up as a whole and the same parties be responsible for the apparatus and all connected with it.

This is a live question.

W. S. Finlay: As an item of interest in connection with

the elimination of cinders, I wish to state informally that we have had in operation for about four months induced draft fans, the blades of which are specially designed to separate the cinders from the flue gasses. Preliminary tests made upon equipment indicate the fact that the manufacturers of the B. F. Sturtevant have met their guarantee of 70 per cent elimination.

THE CHAIRMAN: I have seen a number of these installations, one at Milwaukee, where they told me that since last May they have made observations on dust and water from pulverized fuel, and they cannot find any deposit of dust on the Milwaukee roofs. They say it goes from six to ten miles away, and then comes down in a moist form, as dew or rain comes down. The refuse or ash from pulverized fuel will stay in the air as cigar smoke does, before settling.

HAROLD ALMERT, Chicago: Pulverized coal seems to have a very promising future, but for most purposes it is like an unbroken broncho—not under perfect control. Most representatives presenting pulverized coal-burning devices dwell on the intense heat they are able to produce, and that is their principal weakness. The heat produced is too intense; we have no brick work that will stand it.

Cement manufacturers have had the broadest experience with the manufacture and use of powdered coal, and much can be learned from their experience.

The preparation of pulverized coal by outside plants has been mentioned. I imagine that the reabsorption of moisture would prove an obstacle to this practice. Two per cent of moisture seems to be the maximum permissible for good operation, and to maintain this powdered fuel would have to be shipped in airtight containers.

Powdered coal is being used very satisfactorily for other than boiler firing. The resulting dust which is ash has to be cared for in urban centers. In small plants it is not so easy, but in large central stations, if we get to use powdered coal, the ash or dust can readily be handled by the Corona or Cottrell process of electrifying the dust particles in a chamber or in the stack by static electricity and collecting them in the base of the stack.

Many cement plants are now equipped so that they recover

95 per cent of the dust, which would otherwise go out of the stack.

THE CHAIRMAN: Is there any further discussion? There must be someone else here ambitious to burn pulverized fuel.

I. E. MOULTROP: I would like to suggest that you state something to the audience in relation to the Schultz scheme.

W. L. ABBOTT, Chicago: The device referred to has been installed under a boiler at the University of Purdue and has some very original principles. When I first saw the stoker some months ago it was working fine, but later when I organized a party of half a dozen engineers to show them what I had found, it was working bum. (Laughter.) However, I still have confidence in it.

It is a device to burn ground coal rather than pulverized coal, and consists essentially of a circular furnace about the size and shape of a 3-foot bass drum, placed horizontally and having a 12-inch hole in the bottom head and a 24-inch hole in the top head. Into this furnace the ground coal is projected tangentially in a current of low-pressure air and burns while whirling in this circular box. The gases escape through the hole in the top, while the fused ash runs out through the hole in the bottom. Due to the whirling motion, the coal runs around on the interior circular surface and is gasified during the whirling, and because of the whirling motion the dust cannot escape as such with the flame, but is held in the furnace until it is gasified as combustible or fused as ash.

The largest permissible size of coal, according to the inventor, is what would pass through a ⅛-inch round hole, which is, of course, far from the 200-mesh size to which coal must be ground when used in an ordinary pulverized coal burner. It is not necessary to dry the coal before grinding.

It may be possible to burn coal of still larger particles, and if that be the case, a supply for such a furnace could be obtained by sifting the fine coal out of ordinary screenings. If that can be done, it will greatly simplify the so-called pulverized coal problem. (Applause.)

THE CHAIRMAN: It was under a 250 h.p. boiler and gave 150 per cent rating at about 81 per cent boiler efficiency.

Mr. Abbott: Professor Young of Purdue University has made tests on the furnace, which will be published soon. He reports an efficiency considerably above 70 per cent, which is very high for our ordinary Illinois coal. A high ash is not so objectionable as it is in an ordinary furnace, as the impurities that go in with the coal eliminate themselves by melting and running out.

The Chairman: The next is on the subject of Burning of Lignites, and I will call on Mr. Flagg of the Electric Bond and Share Company, to say a few words.

S. B. Flagg, New York City: In the Report on the Burning of Lignites it was pointed out there is a difference between the sub-bituminous and the lignite coal. It seems important to emphasize this at the present time, owing to the popular impression that all Western coals are lignites; in fact, even the Iowa coal is often, though incorrectly, so classed. With a difference of 3,000 B.t.u. in heating value, and differences of 10 to 15 per cent in moisture content, between lignites and sub-bituminous coals they necessarily present different problems of combustion.

Storage experiments have been referred to in the paper. The first open storage pile, which contained about 75 tons of the Texas lignite, up to the time fires developed from external causes, had shown a maximum heating up to about 115 degrees. This was about 25 per cent above the atmospheric temperature.

The second pile, of about double the quantity,—about 150 tons—was put in storage in January of this year, and a recent report as to its behavior indicates only a slight evidence of heating, this occurring after rainfall, and the heat dissipated itself rather quickly after the rain ceased.

In the case of this second pile, samples taken from the surface and from the interior of the pile show there is no change in the moisture and ash content of the fuel in the interior of the pile. There is a loss of moisture on the surface, and consequently a higher heating value is shown for the sample taken from the surface. The dry coal ash content is substantially the same as in the interior of the pile. The moisture-and-ash-free heating value shows a loss of 400 B.t.u. out of 12,400.

In the case of the bin storage, samples were taken at the

time it was placed in storage in May of last year, and again in December, and then in February of this year. These were taken some distance below the surface of the bin and they showed no change in the moisture-and-ash-free heating values of the samples. The heating values on the as-received basis showed some difference, due to variations in the moisture or ash content; but the samples taken were not large and the variations are only such as might be expected in different parts of the bin.

With reference to spontaneous heating, there is nothing to add to what is in the report except to say that there has been no further heating of the fuel in the bin.

We are sorry not to be able to report more on the combustion of these fuels. On the under feed type of stoker the Report shows some difficulties encountered, and it also states some efficiencies shown. Emphasis might be placed at this time on the importance of air distribution through the tuyere plates of the underfeed stoker. There is a decided tendency for the air to blow holes in the fuel bed and blow fuel down on the dump plates, owing to the motion in this type of stoker. On the natural curve type, I am sorry we have not been able to resume work, and there is nothing further to add at this time. In the case of the forced draft travelling grate, the Coxe stoker, only a few tests have been run to date, and these have shown efficiencies of approximately 65 per cent at boiler rating, and maximum rating of 155 per cent. There has been some difficulty getting the fuel to feed properly, as the hopper design of this stoker is worked out primarily for the fine sizes of anthracite; and also due to the inability of the plant where this is located to get satisfactory crushing. This will probably be eliminated and further results on this type of stoker will be available later.

The report points out that low furnace temperatures are encountered in burning lignites. The lignites require as high a temperature as we can arrange the furnaces to give and there appears to be no danger of overstepping the limits of safety in this respect.

T. A. Marsh, New York City: In classifying these fuels, I would say that sub-bituminous coal is composed of a little coal, with some moisture, while lignite is composed of a lot of mois-

ture and a small quantity of coal. When the moisture exceeds 35 per cent, the available heating value of the coal is low.

The development of furnaces and stokers for burning lignites has been retarded, due to the location of the fields. The Texas fields have to compete with the Texas oil fields and those of Oklahoma and Arkansas, but in spite of this, lignites containing over 35 per cent of moisture have been burned. These low heat value coals require very large grate surfaces. We can get good CO_2 and good ash and combustion rates up to 35 pounds per square foot of grate continuously and higher results for short periods.

Referring to the sub-bituminous problem, these coals give no trouble with chain grates. We are burning them at combustion rates of 35 pounds continuously and at higher rates periodically. One plant operates at 225 per cent of boiler rating and with a grate ratio of about one to thirty. There are many plants in Colorado, Wyoming and the western district using these coals. It is easy to get 12 to 14 per cent CO_2 with excellent ash. Large furnaces are necessary.

The Association can therefore consider the problem of burning sub-bituminous coal solved, as there are many operating installations and test data available for any one who is further interested in this subject.

THE CHAIRMAN: I think Mr. McClelland said they allowed a full afternoon for discussion of prime movers; but he should have given us two afternoons. I hope you are not getting tired as we have boiler and turbine room instruments yet. If you have had any experience in getting data for a prime movers report, you will find you have to go through many subjects to find out what will be of interest to the members. For another year the Prime Movers Committee asks you to send suggestions as to subjects in which you are interested to the National Electric Light Association headquarters, "Prime Movers Committee," which Committee will try to answer any questions you send and take advantage of any suggestions with which you favor it.

We will now take up the question of storage of coal. The Chair recognizes Mr. W. L .Abbott of Chicago.

MR. ABBOTT: It seems strange to me that we are still dis-

cussing ways for storing coal and preventing its firing. In Chicago we passed that point several years ago. We know how to store coal so that it will take fire, and we know how to store it so that it will not take fire. We store each year 100,000 or 200,000 tons of Illinois bituminous coal, and we do not have any more fires in the coal pile.

The cause for heating in storage piles is that freshly mined coal undergoes a slight oxidation when exposed to the air, the heating being proportional to the aggregate surface of the lumps. A piece of coal one inch in diameter when exposed to the air at a given temperature will generate a certain amount of heat. If this lump be ground up into pieces 1/100 of an inch in diameter, the surface exposed will be many hundred times greater and the heating will be proportionally increased. If all fine coal is excluded from the pile and nothing but lumps one inch in diameter or larger are stored, the resultant heating will be negligible; or if only fine coal is stored and care is taken in handling it so that the larger pieces will not segregate out by running down the side of the storage pile, the coal may become so packed that air cannot penetrate the pile to any depth, and in this case there will also be no resultant heating. If, on the contrary, a mixture of coarse and fine sizes be so piled that the larger lumps will run down the sides, leaving finer coal in the center, the coarse coal will form passages through which air will circulate—too slowly to conduct away the heat which is being generated but fast enough to support the low temperature oxidation which is going on on the surface of the fine particles. In this way the temperature will slowly rise, so that at the end of a few days or of a few weeks, depending upon the atmospheric temperature, hot spots will have developed in the pile and raised the temperature to the smoldering point, after which the pile will soon be on fire. We have had piles 25 feet high keep without any signs of heating for ten years, and without any perceptible deterioration except some mechanical disintegration on the surface.

Harold Almert, Chicago: I want to take this opportunity to pass on to those present my observations made last year while connected with the Fuel Administration in Illinois.

In the future we must devote more attention to our fuel supply. In the past, if we were located close to an adequate and

low-priced supply, little or no attention was paid to the efficient burning of fuel. Whereas, if we are located where fuel is expensive or the supply uncertain, our study of fuel supply receives some, though not nearly as much attention as it deserves.

Our future coal supply and its cost are going to depend on our study and cooperation with the producers. To bring the price down we must better the producers' load factor, which means taking our annual requirements at a uniform rate throughout the year. This in turn means a study of coal storage and the preparation and selection of coal suitable for storage.

During the coal shortage last Fall, Chicago had a surplus of 30,000 cars a month of Illinois screenings going to demurrage, while there were plenty of plants that could and should use that class of coal to the exclusion of the prepared sizes. In Illinois during the coal shortage, there was a million tons a month surplus of screenings that found no market, and still this coal could all have been used currently or prepared so that it would store safely.

THE CHAIRMAN: Has steam ever been used in putting out fires, that is, injecting steam into the piles?

MR. ABBOTT: I am not aware that it ever has been, and I think it would be dangerous because that degree of heat would generate spontaneous combustion.

MR. RICKETTS: Steam has been used on board ship to stop fires in the holds. It is a regular appliance on colliers and it is effective in close places, but not so in an open pile.

THE CHAIRMAN: You may have thought we did not have any sequence in our discussion this afternoon; it started with the turbine and now it is back to the coal pile.

Now we will go the other way as far as the generator. The next is Condensers.

I would like to say a word as to the space allotted to condensers. It was assigned to a sub-committee, of which Mr. H. P. Wood, of Brooklyn, was chairman. It caught him in the midst of the New York harbor strike, and he worked at the rate of 200 per cent while he worked at it, and he assured me he wrote the condenser report while on a tug boat in New York harbor stealing coal.

THE CHAIRMAN: Boiler and Turbine Room Instruments, and I will call on Mr. Ricketts.

E. B. RICKETTS, New York City: I heartily agree with the authors' statement that, "We are entering into a period when one man will operate all of the boilers from a central point." And I believe that much better efficiencies will be maintained when this is done. I expect to see in the near future boiler plants controlled much as switchboards are now operated.

The necessary instruments for giving practically complete information about boiler operation are now on the market and their installation on large boiler units is undoubtedly justified at the present time, but I have never been able to justify the heavy expense for their installation and maintenance on boilers of 600 h.p. and under.

Many people have the erroneous idea that by hanging an elaborate and ornate instrument on the boiler front they thereby automatically increase the boiler efficiency. Nothing was ever further from the truth. Unless the accuracy of the instruments is maintained, the operators taught how to interpret the readings and the use of the instruments insisted upon by the management, the investment will pass out of the useful into the ornamental class.

Too much stress cannot be placed on the fact that keeping boiler room instruments in shape is not a job for a coal passer when he has nothing else to do, but requires the services of a good mechanic who has some knowledge of the chemistry of combustion and a knack for tinkering.

THE CHAIRMAN: Power Station Auxiliaries. Is Mr. Hirschfield here? (No response.)

It is now half-past five, and there are four subjects left, the resumé of the fuel oil situation, by-products, oil engines, and water power progress. Does anybody wish to discuss any feature of any one of those subjects. (No response.) Is there any general discussion on the report, or on any subject connected with it which we have already passed, and which anyone would like to bring up again. (No response.) There being none, I declare the meeting adjourned.

(Session adjourned.)

SECOND TECHNICAL AND HYDRO-ELECTRIC SESSION

Tuesday, May 20, 1919

R. H. BALLARD, Chairman.

J. E. DAVIDSON, Vice-Chairman.

The Chairman called the meeting to order at 2:30 P.M.

THE CHAIRMAN: Gentlemen, we will convene as the second Technical and Hydro-Electric Session, and the first subject we have for consideration is the report of the Committee on Underground Construction and Electrolysis, Mr. E. B. Meyer, of the Public Service Electric Company of Newark, New Jersey, Chairman.

REPORT OF COMMITTEE ON UNDERGROUND CONSTRUCTION AND ELECTROLYSIS

The work of the Committee on Underground Construction and Electrolysis was actively resumed in 1918 after having been disorganized to a considerable extent by war conditions. The report this year deals with problems of underground construction under fourteen headings.

The war brought about very few new problems in this branch of the industry, largely because underground construction had to be discontinued in most cities by the excessive cost of material and the extreme shortage of labor.

However, a considerable amount of additional information has become available bearing on problems previously discussed, and it is the aim of the Committee in this year's report to bring this information to the attention of member companies.

As in previous reports, it will be noted that the subjects of current carrying capacity of cables, dielectric losses and cable failures are again discussed.

These subjects are of vital importance to the central station industry, as in the larger companies a considerable portion of their total investment is in underground construction.

Information on the current carrying capacity of cables under various conditions will be welcomed by operating companies as well as by cable manufacturers.

Work done by member companies in different sections of the country under various temperature conditions will be of value.

Member companies are, therefore, urged to keep an accurate record of the load on their transmission cables, measurements of temperature and data on the characteristics of the duct line.

If information of this kind is secured by the Committee, it is very probable that a definite recommendation on these subjects will be forthcoming in the near future.

Member companies are again urged to communicate with the Underground Committee regarding their problems, with a view

Manuscript of this report was received April fourteenth.

either to assisting in their solution or in making the information available for others. It is only in this way that the Committee can be of maximum benefit to the industry as a whole.

CURRENT CARRYING CAPACITY OF CABLES

The marked change in the load curve of central station companies, occasioned by taking on large blocks of load to serve industries working on a twenty-four hour basis, has necessitated the operation of all classes of equipment at a higher load factor.

This method of operation has, among some companies at least, led to an unusually large number of cable failures and, consequently, it has been necessary to study the subject with a view to outlining a rational scheme for cable operation.

One company has developed a plan by which the cable is given a seasonal rating based on the average temperature in an idle duct.

Fig. 1 shows the graphical method of determining the maximum continuous loading of cables varying in size from No. 1 to 350,000 c.m., operating at 13,200 volts.

The abscissæ of the curves are temperatures, the average temperatures of outside air for the locality under consideration having been determined from temperature records. A number of tests gave 40 deg. fahr. as the average temperature difference between the outside air and the conduit system, and it is upon these test results that the chart has been developed.

It will be noted that there is an appreciable difference between the summer and winter ratings. For instance, a 350,000 c.m. cable has a winter rating of 296 amperes continuous loading against a minimum rating in July of 210 amperes.

This method of rating cables has worked out very satisfactorily, but some modifications might be found necessary for other systems, depending on the heat dissipating characteristics of the particular conduit line.

The strictly logical way to arrive at the proper loading of any cable is to determine by an actual temperature survey what might be called the constants of each main duct line. With this information available, the rating of cables based on maximum allowable operating temperatures is comparatively simple.

As regards the artificial cooling of duct lines, little develop-

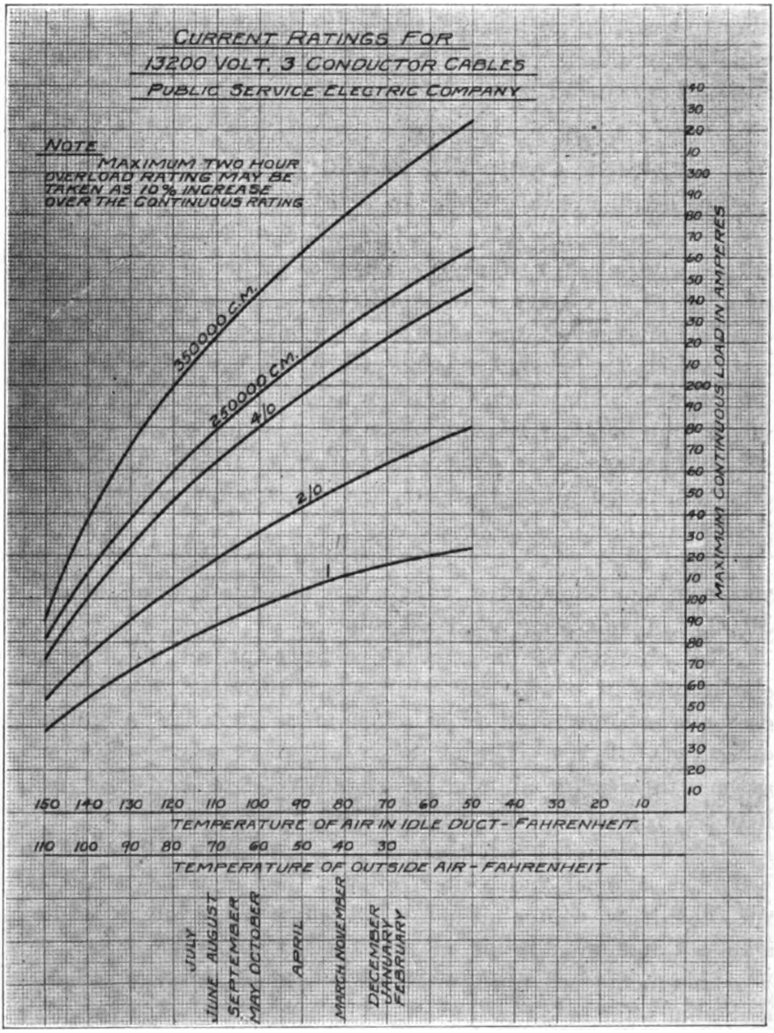

Fig 1

ment work appears to have been done, and where a large part of the conduit line has poor heat dissipating qualities, little can be done except to limit the loading of the cables so as to keep them within safe temperature limits.

In case of local hot spots, however, it is usually possible to obtain relief through one of the various methods of artificial

cooling. Previous reports have discussed the use of the water sprinkling system and the scheme of installing air blowers in manholes.

One company reports that a bad local hot spot was cleared by uncovering the conduit line for a distance of about twenty feet and backfilling the excavation with heavy clay to replace the sandy fill which had been causing the trouble.

The temperature in an idle duct at the point of excavation was reduced in this way from approximately 160 deg. fahr. before excavating to about 75 deg. fahr. after backfilling with clay.

Where local conditions do not permit the use of this method, it will be found advantageous to install a specially ventilated manhole at the point where the temperature is excessive. This scheme has been found to relieve cases of overheating caused by the proximity to the duct line of bake ovens or live steam mains.

The subject of the current carrying capacity of cables is closely allied to the study of underground cable failures and it is hoped that the investigation of these troubles will be so thorough as to make temperature surveys a matter of routine.

It is only in this way that the rule-of-thumb methods of rating cables can be discarded for a more logical method based on an accurate knowledge of conditions.

DIELECTRIC LOSSES IN CABLES

In previous reports the subject of dielectric losses has been discussed in a general way, and it has been pointed out that the magnitude of these losses and their variation with temperature have a very marked effect upon the operating characteristics and the life of a cable.

The subject is still under discussion among engineers of member companies, and, while no fixed set of rules can be formulated at present, there is considerably more information available now than at the time of the last report.

One company, at least, and probably several others, have written into their high tension cable specifications a clause requiring manufacturers to submit with their bids a table or curve guaranteeing values of dielectric loss which will not be exceeded under various temperature conditions.

Fig. 2 shows the variation in dielectric loss with temperature,

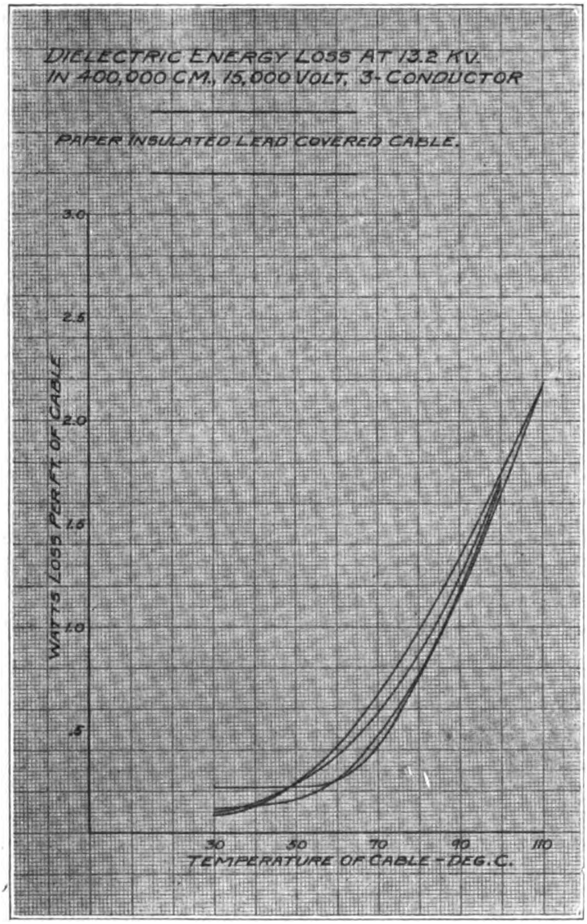

FIG 2

the values having been plotted from guarantee figures submitted by manufacturers at the time of bidding. These curves are confined to cables impregnated with a mineral oil base, as there seems little reason to doubt its superiority over a rosin oil base as regards dielectric losses.

This is borne out by Fig. 3, in which are plotted the results obtained from comparative tests of cables identical in size and construction, but impregnated with rosin oil in the one case and mineral oil in the other.

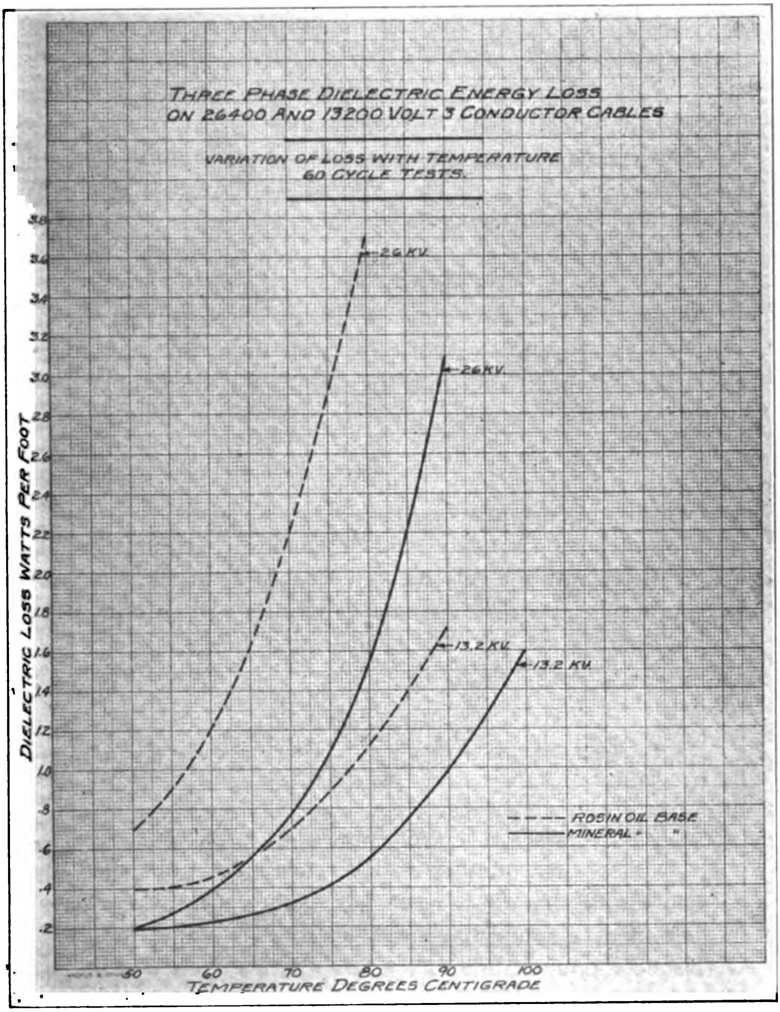

FIG 3

Two rather important points are to be noted. First there is a marked difference in the watts lost per foot, between the rosin oil and the mineral oil compound. The difference amounts to more than two watts per foot at 80 deg. cent. in the case of the 26,000 volt cable, with a proportionate difference at the lower voltage.

Second, the curve for the mineral oil compound shows a fairly gradual slope, while the curve for the rosin oil compound has a steep slope throughout and attains very high dielectric losses at the upper range of temperature.

These characteristics are of very great importance in case the cable is installed in a duct line where hot spots are likely to develop. The cumulative effect of high temperature on dielectric loss would be particularly marked in such a case and the failure of the cable would occur in a very short time.

While it is true that mineral oil has better operating characteristics as regards low dielectric loss, there are, undoubtedly, other factors which enter into the selection of the proper impregnating material. It is quite possible that certain mineral oil compounds, in spite of their excellent dielectric properties, would become too fluid at high temperatures, leaving the insulating material dry in certain sections and thereby liable to breakdown.

One member company has completed an elaborate series of tests to determine the relative value of rosin oil and mineral oil compounds, as a medium for impregnating paper insulated cables. and its findings are given herewith:

SUMMARY

The results of the several series of tests may be summarized as follows:

(*A*) *Oils—Dielectric Strength*

Tests on a number of different types of oils showed that compounds having a rosin base have, even at normal temperatures, a somewhat lower dielectric strength than mineral base compounds, and as the temperature increases the breakdown voltage of the mineral oils remains nearly constant, while that of the rosin compounds falls to a fraction of its original value.

(*B*) *Comparative tests were made on cables to determine:*

1. Dielectric Leakage Current at from 3 to 15 kilovolts at both 25 and 60 cycles.
2. Dielectric Losses in watts per foot throughout the same range.
3. Power Factor at 15 kilovolts, 25 and 60 cycle.

4. Insulation Resistance.
5. Dielectric Strength.

These tests were made on samples of single conductor 200,000 c.m. cable, insulated with 6/32 in. paper and lead covered 1/8 in., different impregnating compounds being used.

The results may be briefly summarized as follows:

(1) *Dielectric Leakage Current:*

At 25 cycles, at 20 deg. cent. was more than twice as great in cables using rosin oil as in those using mineral compounds, and at 100 deg. cent. was over four times as great.

At 60 cycles, at 20 deg. cent. rosin oil 25 per cent higher, and at 100 deg. cent. about 130 per cent higher.

At both 25 and 60 cycles, the current was only about 12 per cent higher at 100 deg. cent. than at 20 deg. cent. in the mineral compounds, while it increased over 100 per cent in the rosin oil compounds.

In the rosin oil compounds the leakage current was practically constant from 0 deg. to 60 deg. cent., but above this critical temperature it increased very rapidly. The mineral compound showed practically a straight line increase through the whole temperature range.

(2) *Dielectric Losses: (Watts per foot)*

Dielectric losses follow in general the leakage current figures just given, the increases at higher temperatures being, of course, much greater as they vary with the square of the current. The losses at 60 cycles are in all cases greater than at 25 cycles, and at the higher temperatures the losses in the rosin cables are six or eight times greater than in the mineral oil cables.

(3) *Power Factor:*

The power factor is slightly greater at 25 than at 60 cycles for all temperatures. It is less in the rosin cables for the lower temperatures, but above 40 deg. or 50 deg. cent. is greater in the rosin cables than in the mineral oil cables.

(4) *Insulation Resistance:*

The insulation resistance on direct current test is uniformly less for the rosin compounds, and decreases for both

compounds as the temperature increases, but while it falls to an extremely low value at 90 deg. cent. for rosin compounds, it is still in the order of megohms for the mineral oil compounds.

(5) *Dielectric Strength:*

The rosin oil cables showed a slight decrease in dielectric strength at the higher temperatures, while that of the mineral oil cables was practically constant up to 100 deg. cent.

As to the relative values, one set of rosin oil samples tested about 20 per cent higher and another set from 15 to 20 per cent lower than mineral oil cables.

Comparative values of insulation resistance and dielectric losses are shown graphically in Figs. 4 and 5.

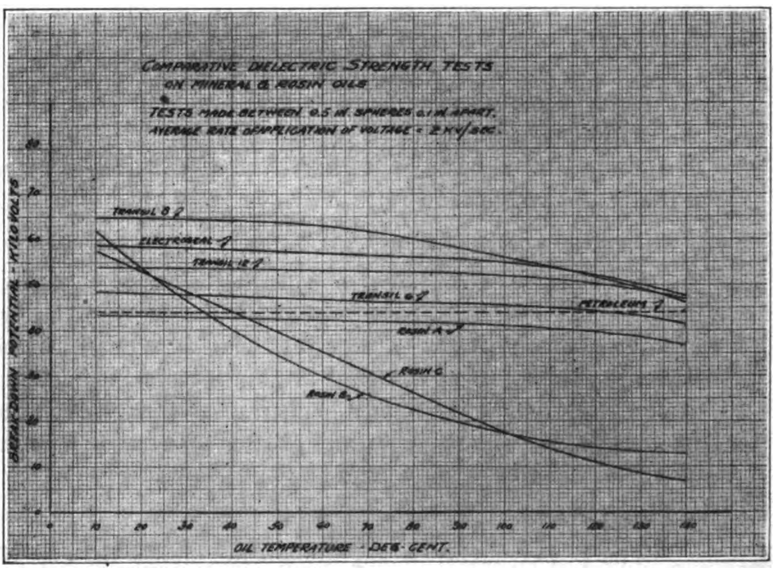

FIG 4

As a result of the foregoing tests, the company now specifies either a mineral oil compound or a compound containing less than 15 per cent of rosin oil.

Research work is being done along these lines by the various cable manufacturers, and until such time as the results of addi-

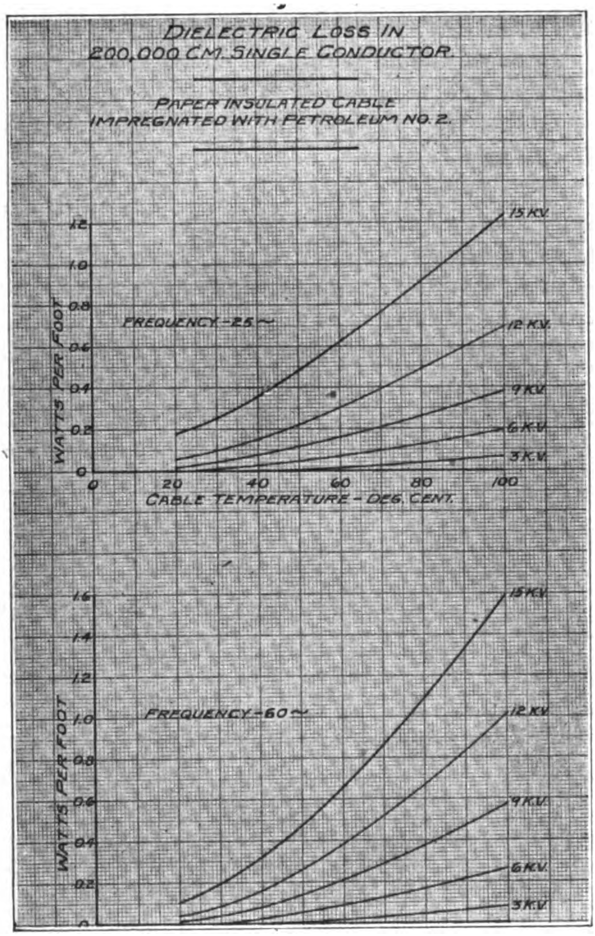

FIG 5

tional experiments are available the Committee is not prepared to give its unqualified approval to the use of mineral oil compounds to the exclusion of all others.

CABLE FAILURES

The operation of cable systems, even more than other classes of central station equipment, requires the maintenance of a com-

plete and systematic record of all failures to determine their origin and cause and to permit of taking measures which will guard against their recurrence.

The matter of observing and recording all details in connection with service interruptions may at times require the inclusion of facts which seem irrelevant. However, the increase in capacity and the extension of electrical systems tend to make disturbances more destructive, and it is, therefore, important that all companies record every detail which may have even a remote bearing on cable failures.

In order that member companies might get some idea of the failures which may be expected in the operation of underground systems, the Committee has prepared a summary of the experience of member companies operating high voltage systems.

CABLE FAILURES FOR YEAR 1918

COMPANY	MILES CABLE	VOLTAGE	CABLE FAILURES	JOINT FAILURES	TOTAL FAILURES	FAILURES PER 100 MILES	NEUTRAL GROUNDED
NEW YORK	96	11,000	0	0	0	0	YES
"	128 6	15,000	10	30	40	31 1	"
"	12 6	25,000	0	0	0	0	"
DETROIT	266 6	26,000	8	22	30	11 2	"
TOLEDO	27 0	23,000	2	1	3	11.1	"
BALTIMORE	153.3	13,200	13	7	20	13.0	"
BOSTON	45.4	6,900	5	1	6	13 2	"
"	306.6	13,800	17	11	28	9.1	"
"	29.0	25,000*	0	1	1	3 5	"
PITTSBURG	25.5	22,000	17	0	17	68.0	"
"	104 2	11,000	39	0	39	39.0	"
NEWARK	234.0	13,200	44	21	65	27 7	NO
SAN FRANCISCO	90.0	15,000	3	2	5	5 5	"
CHICAGO	450.0	9,000	10	2	12	2 7	YES
"	240 0	12,000	14	0	14	5.8	"
"	80.0	20,000	8	0	8	10.0	"
TOTAL	2202.3	——	190	98	288	13.1	——

* OPERATED AT 14,000 VOLTS

THE ABOVE TABULATION EXCLUDES ALL FAILURES DUE TO MECHANICAL INJURY, ELECTROLYSIS AND CAUSES OTHER THAN THOSE USUALLY EXPERIENCED IN OPERATION.

TABLE I

Table I shows the number of miles of cable installed and the failures per hundred miles of cable in service for the year 1918. This statement of failures does not include failures due to mechanical injury, electrolysis or causes other than those normally experienced in operation.

It will be noted that replies from member companies operating a total of 2202 miles of cable at voltages from 6900 to 25,000, indicate that the average failures for all classes of service amount to 13.1 per hundred miles of cable.

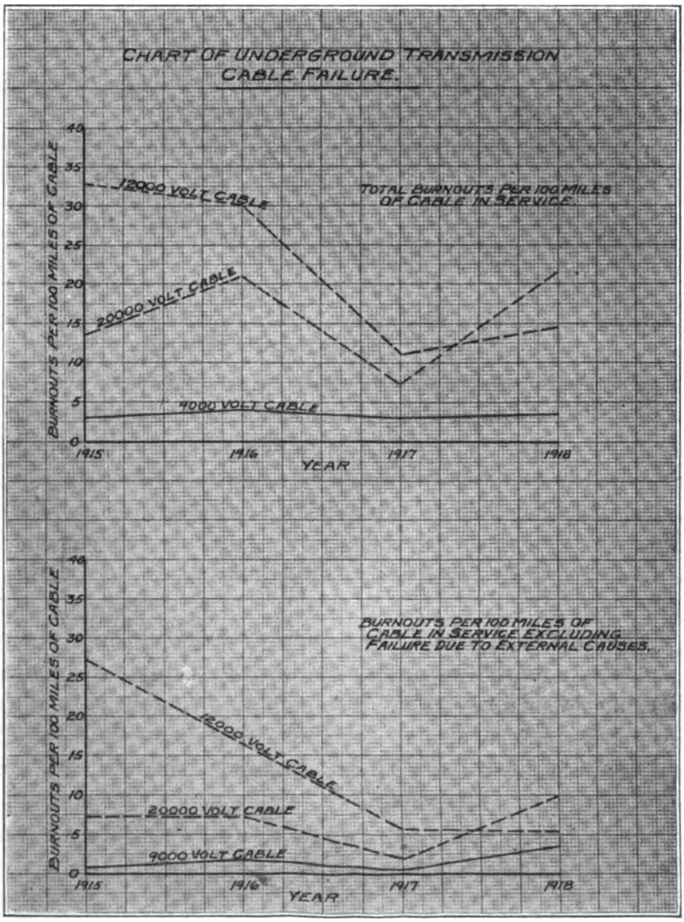

FIG 6

It was impossible for the Committee to obtain a record of all failures over a period of years, but the chart in Fig. 6 is typical of what may be expected in a well-designed and properly maintained system.

The curves in Fig. 6 show the total burnouts per hundred miles of cable in service at voltages of 9000, 12,000 and 20,000 volts, and also the failures per hundred miles of cable in service, excluding failures due to external causes. This chart covers an average of approximately 475 miles of 9000 volt, 200 miles of 12,000 volt and 80 miles of 20,000 volt cable.

The Committee intends to make this cable failure record a permanent feature of its annual report and for this reason member companies are urged to cooperate by keeping a detailed record along the general lines indicated.

The Underground Committee report for 1916 included a recommended standard form for reporting failures, and if this form is adhered to the record of failures for the various companies will be on a comparable basis.

CABLE FAULT LOCATION

The method of locating cable faults employed by one company with excellent results, consists of a transformer known as the analyzer, so arranged that a number of different voltages may be applied to break down faults of different resistances, an interrupter which is used to apply a signal current of different frequency from that of the regular live current, and various forms of exploring coils for tracing the signals given out by the interrupter.

The first step in locating a short circuit or ground is to apply a suitable potential by means of the transformer to break down the fault to a solid ground. The signaling current is then applied through the interrupter to the faulty conductor, and the trouble man follows the cable with an exploring coil until he loses the sound of the signaling current, when he knows that he has passed the fault. This gives quick and accurate results and with a little experience a man can easily locate faults.

In connection with the outfit are a number of so-called load coils, which are used to limit the current which can flow into the

fault. It is also necessary to have an alternating current supply of 110 volts, of about 50 amperes capacity, also one or more standard line transformers (one with two primary coils and two secondary coils), to give a pressure, when properly connected, of at least 50 per cent of the normal operating potential of the line in trouble.

This same test may be used for locating faults on street circuits, overhead and underground lines, leaking insulators, tree grounds, Edison tube faults, faults in split conductor cables and for identifying cables. In identifying cables by using an interrupter on each wire, more than one wire may be traced at the same time. This is accomplished by taking one or more screws out of the commutator, which changes the wave form of the signal current and gives different sounds in the telephone receiver on the exploring coil. An experienced man can frequently analyze the type of fault before leaving the station by the sound of the signaling circuit.

Another method in use by a number of the large companies is the well-known Murray loop test. The Wheatstone bridge method is used in this scheme. As in the previous scheme, a good conductor parallel to the faulty one is used and the two are joined at the further end from the testing point. The resistances of the two paths to the ground are then found by adjusting the standard resistances so that there is no galvanometer deflection, and calculating by the formulae for the Wheatstone bridge.

After the resistances of the conductor paths to ground are found, the distance to the fault in feet or miles may be found by dividing the resistance by the resistance per foot or mile.

One member company has been using a fault localizer for cable faults, which has given very good results. It estimates that 70 per cent of its faults have been located within one section by using this apparatus, which is shown diagrammatically in Fig. 7.

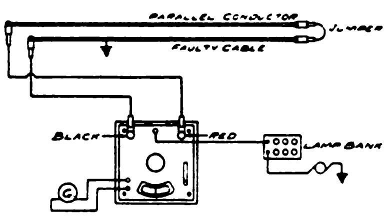

Fig 7

The cable is first tested by means of a lamp and, if it shows a high resistance ground, it must be broken down by applying a sufficiently high voltage.

The fault localizer is then connected to the faulty conductor and a good parallel conductor. At the other end these two conductors are joined. The localizer is also connected to ground through a lamp bank. The localizer is then regulated by means of a dial switch until the galvanometer shows no deflection on closing the key. The reading on the localizer instrument scale then gives the per cent length of the feeder from the point where the test is being made to the location of the ground. Direct current is used for the test. This is a very simple method of locating grounds, and is based on the Wheatstone bridge method.

FIREPROOFING OF CABLES IN MANHOLES

The several methods of fireproofing cables in manholes have been described in detail in previous reports of this Committee, and while a survey of present practice by members companies has not disclosed any new methods, the information is of interest as it shows the general trend.

Practically all member companies employ one of the well-known methods of covering their cables, although some still adhere to the practice of installing shelves in the manholes without employing any form of covering. A few companies cover all of their cables where exposed in manholes. The general practice, however, is not to cover the low voltage mains and series arc cables.

Cement covering seems to be the one in most general use today. This consists of a covering of Portland cement mortar, usually one part of cement to one part of clean sharp sand, applied rather dry to a thickness of from one-half to three-fourths of an inch. The addition of plaster of Paris is being tried to produce quicker results in setting. The cement is applied over a spiral wrapping of small rope or some form of metal lath.

The superiority of the cement covering over the various types of asbestos covering seems to be firmly established among member companies which have used both types. There appears to be, however, a considerable difference of opinion regarding the comparative merits of rope and metal lath for reinforcing the

cement covering. Tests were made by the New York Edison Company in 1916 to determine the relative protection against external fire afforded by the two forms of covering. Two samples were employed, one of which had a winding of one-fourth-inch rope and the other a fireclay lathing as a base. The test showed clearly the superiority of the non-combustible reinforcement, as this material did not permit the cement covering to open up and expose the cable to the action of the flame. Other companies using the rope base state that it affords ample protection and that it is much easier and cheaper to apply.

One company is abandoning the use of the metal lath because the iron wire, on account of its magnetic properties, interfered with the operation of fault locating equipment.

In general, it may be stated that the various types of cable covering will protect the cables from troubles of external origin, except where there are general manhole fires or severe electric arcs of some duration in the immediate vicinity of the cable. The covering also lessens the probability of damage to unprotected cables, but cannot be relied on to confine the trouble within itself. Usually the covering is blown off the damaged cable where the failure occurs in service, although at times the covering fails to reveal the fault.

There seems to be a question as to whether or not the heat radiating qualities are adversely affected by the covering, but it is generally believed that the covered cable in the manhole has a better chance to radiate its heat than the uncovered cable in a conduit line.

SELECTION OF DUCT SIZE

The Committee has received several inquiries from member companies regarding standard practice in installing underground conduits, with particular reference to the proper size of duct for high tension transmission cables.

It is always advisable to bear in mind the maximum size of cables which will be used in the system, and for this reason it is necessary to select the size of duct after a consideration of probable future developments.

The cost of conduit construction among the larger companies represents a large part of the entire plant investment, so

that great care must be exercised in determining the kind of material and the type of construction to be used.

The replies to a questionnaire sent to a number of large operating companies, whose type of construction can be considered fairly representative of conditions throughout the United States, seem to indicate that fibre conduit is rapidly coming into favor and is at present considered standard construction by several of the large companies.

Some companies, however, still use tile conduit, and one company states that stone pipe conduit best meets its requirements because of its arc resisting qualities and because there is very little danger of communication of trouble from a faulty cable to the cables in adjacent ducts.

The consensus of opinion is that 3½-inch ducts are the largest that need be installed, but one company is standardizing on 4-inch fibre duct for cables of approximately 2¾-inch diameter. The reason given for the selection of this size is the ease in installation and the better ventilation of the system after the cable is placed in service.

Several companies use 4-inch and even 4½-inch duct in special cases where it is necessary to avoid sharp bends at the entrance to stations or substations.

In most city streets, however, it is necessary to keep the size of the whole duct line within reasonable limits and, consequently, the size of the individual ducts must be kept down. It should further be borne in mind in considering this problem that even where there is ample space to install 4-inch in place of the usual 3½-inch ducts, the size of the conduit line, and, consequently, its cost, will be from 15 to 20 per cent higher.

A 3½-inch fibre conduit is large enough to permit of the installation of a cable having an outside diameter of 3.2 inches, the only difference in the method of installation being the use of a special cable eye instead of the basket or other form of grip usually employed for pulling-in.

Table II shows the largest size of duct in use, together with the kind of material and the largest diameter of cable installed. This summary also shows the maximum kv-a. transmitted per circuit and such other information as has a direct bearing on the problem of conduit sizes.

DATA ON DUCT SIZES										
LOCATION	DUCTS			CABLE						REMARKS
	SIZE	KIND	MAXIMUM NO.	APPROX. OUTSIDE DIAMETER	WEIGHT POUNDS PER FOOT	CONDUCTOR SIZE	INSULATION	VOLTAGE	KVA	
BALTIMORE *	3¾" 3½"	TILE	20	3"		4/0-3 CONDR.	$\frac{9 \times 6}{32}$	26000		HAVE FOUND 3½" DUCT LARGE ENOUGH.
NEW YORK	3"	SINGLE TILE	18	2.82"	14.1	450000 CM 3 CONDR. 350000 CM SECTOR 350000 CM SECTOR		8000 6600 15000	3500 KW. 7500 KW.	3" TILE DUCT PREFERRED IN CLOSELY POPULATED SECTIONS SINGLE TILE DUCT IS USED. TILE DUCT RESISTS MUCH BETTER ACTION OF DESTRUCTIVE AGENCIES, SIMPLER TO REPAIR ITS BREAKS AND EASIER FOR PULLING CABLE.
LOS ANGELES	3"	FIBRE	20	2.96"	10.37	4/0-3 CONDR.			5000	PREFER FIBRE DUCT, LESS DANGER FROM ELECTROLYSIS, LOWER COST OF COMPLETED CONDUIT, MINIMUM OF LOSS IN HANDLING AND MINIMUM OF SKILL REQUIRED ON INSTALLATIONS. 3½" DUCT IS PREFERRED ALLOWS INSTALLATION OF TWO 100,000 C.M. LOW TENSION CABLE
DETROIT	3⅝" (OLD) PROPOSED 4" (NEW)	SINGLE TILE AND FIBRE	20	2.82"	8.6	2/0-3 CONDR.	$\frac{9 \times 7}{32}$	24000	7000	FAVORABLY DISPOSED TO INSTALLING FIBRE DUCT, LOWER COST AND BETTER CONSTRUCTION
MONTREAL	3½"	TILE AND FIBRE	18	3.08"		4/0-3 CONDR.		13000		BELIEVE 3½" DUCT LARGE ENOUGH TO ACCOMODATE CABLES CARRYING THE MAXIMUM AMOUNT OF POWER WHICH SHOULD BE CONCENTRATED IN ONE DUCT OR CABLE. PREFERS SINGLE TILE AND FIBRE DUCTS
PITTSBURGH	3¼"	TILE		2.7"	10	1000,000 CM. DUPLEX		220		PREFER 3½" OR 4" DUCT TO ALLOW HEAT TO MORE RAPIDLY RADIATE FROM CABLE. FINDS TILE DUCT CHEAP AND GOOD INSULATOR WHEN CABLE BURNS OUT IN DUCT
BOSTON	3½"	FIBRE	16	3.1"	11	300000 CM 3-CONDR.	$\frac{9 \times 6}{32}$	25000	10.000 max 7.500 contin.	FIBRE DUCT PREFERRED, EXPERIENCES LESS ELECTROLYSIS CORROSION AND BETTER CONSTRUCTION 3½" DUCT LARGE ENOUGH
CHICAGO	3½"	STONE	20	3"	11	250,000 CM 3-CONDR.		22000		PREFER STONE DUCT, CHEAPER AND ARC RESISTING. 3½" DUCT WOULD BE A PROPER SIZE.
LOUISVILLE	3" (OLD) 3½" (NEW)	TILE AND FIBRE (OLD) FIBRE (NEW)	16	2.625"	9.2	250000 CM 3-CONDR. SECTOR		18000	5000 Max.	PREFER FIBRE DUCT, BETTER CONSTRUCTION AND LOWER COST.
NEWARK	3½"	FIBRE	24	2.9"	10.3	250,000 CM (SECTOR) 3-CONDR.	$\frac{9 \times 9}{32}$	26400	9000 max 7500 contin.	PREFER FIBRE DUCT, BETTER CONSTRUCTION AND LOWER COST. 3½" DUCT OF SUFFICIENT SIZE TO ACCOMODATE CABLE CARRYING MAXIMUM POWER WHICH SHOULD BE CONCENTRATED IN ONE CABLE.

* Municipal conduits

TABLE II

The replies seem to indicate that from 5000 to 7500 maximum kv-a. per circuit is usual practice in underground transmission work. The general opinion is that it is not desirable to concentrate more than 7000 to 8000 kv-a. in a single circuit, and that 3-inch outside diameter is about the largest cable now in use.

The Committee's report for 1916 carried a recommendation that 35,000 kv-a. is the maximum load which should be carried in a single duct line, and in this connection the Committee also recommends that the size of a single conduit be limited to sixteen to twenty ducts.

INSTALLATION OF SUBWAY TRANSFORMERS

Subway type transformers are now used extensively, and where the installation of such equipment is under consideration care must be exercised in the design of the transformer vault or manhole.

Some member companies employing alternating current systems where the load density is high, have as much as 20,000 kilowatts of transformer capacity installed underground, while a number have over 5000. Under these conditions the provision of ample manhole space in the limited confines of the city street becomes a real problem.

In most of the older systems, transformers have been installed in any available manholes of the distribution system, but later practice is to build special vaults for them. Where large concentrated loads are to be served, it is often desirable to secure space under sidewalks or in the basements of buildings, placing the transformer as close as possible to the load to reduce the amount of secondary feeder copper.

Statistics obtained from eight of the larger member companies show that the manhole type transformers installed vary in size from 1 to 150 kv-a.; averaging about 36 kv-a. A number of companies use nothing smaller than 50 kv-a.; but one company has an installation of 450 kv-a. in a single manhole, necessitating forced ventilation. In general, however, the kv-a. capacity per manhole is limited to 200, reaching 300 kv-a. as a maximum.

Most companies employ empirical rules for limiting the maximum capacity of transformers installed in a given manhole

These are expressed in a variety of ways. A survey of the data furnished indicates, however, a general agreement in the amount of heat dissipated through the walls, roof and floor. For a dry manhole this varies from 3.7 to 4.8 watts per square foot with temperatures of air in manhole varying from 100 deg. to 120 deg. fahr.

This heat transfer constant is an average value and may be increased or reduced, depending on the nature of the surrounding soil. Furthermore, the designer in arriving at the amount of heat loss in the transformer should not base his calculations on either the name plate rating or the peak load, but should draw up a predicted load curve and design the transformer manhole

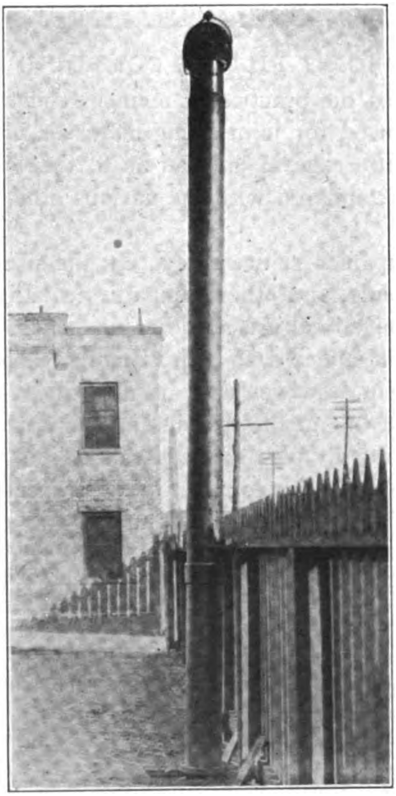

FIG 8—STANDPIPE TO PROMOTE CIRCULATION OF AIR THROUGH MANHOLES

to meet operating conditions as nearly as they can be foreseen.

Practically all companies use manholes with ventilating covers and a few use standpipes similar to that shown in Fig. 8 to promote air circulation. Previous reports of the Committee have described the various schemes of forced ventilation where this practice is employed.

Forced ventilation, however, is at best a makeshift and the failure of the cooling apparatus is likely to result in a rapid temperature rise and the burning out of the transformer.

The use of forced ventilation is, therefore, not recommended except in extreme cases where conditions will not permit of eliminating the cause of overheating by providing the necessary additional vault space.

JOINT FILLING COMPOUNDS

A survey of the practice of member companies with regard to compounds used for joint filling materials indicates that there is still some difference in opinion as to the comparative merits of paraffine as compared with the various other compounds now in use.

Some companies criticize severely the use of paraffine for high tension joints, and other companies equally as large and of as wide experience will use no other material. The same difference of opinion appears to exist among cable manufacturers. The disagreement, however, appears due not so much to the compounds as such, but to the manner in which they are used.

It is undoubtedly true that a paraffine joint when made with extreme care will be the equal in every respect of a joint made up with semi-fluid compound, but unless the splicer is familiar with the characteristics of paraffine (as regards its property of contraction and tendency to leave voids) and is otherwise skillful and reliable, paraffine is likely to give trouble.

Of course, the same statement might be made of all joint filling compounds, but in a lesser degree. However, it is probably true that under ordinary conditions as regards splicing, the joint filled with semi-fluid compound is less likely to fail than the paraffine filled joint.

Because there is still a difference of opinion, the Committee is not prepared to make a definite recommendation at this time,

but will continue its investigation and endeavor to obtain a tabulated statement of comparative operating records of joints filled with paraffine and other types of filling compound.

NEUTRAL OF EDISON THREE-WIRE SYSTEM

A questionnaire sent out to seven companies operating Edison three-wire direct current systems brought out a number of interesting facts as to the size and weight of copper in neutral feeders and mains, also methods of grounding and other details of construction and operation.

Method of Establishing Neutral

The neutral is established and balanced voltage maintained on nearly all of the systems by taps from transformers, balancer sets or a combination of these two methods. Two companies depend upon transformer taps only, while others use the different methods in different substations. One company has three-wire motor generator sets in most of its substations. Only one company permits unequal battery discharge to assist in maintaining balance; all others keep the batteries floating by means of end-cells.

Station Grounds

Four of the companies connect the neutral bus to the water mains, and of these two connect to building framework in addition. Five connect to ground plates or pipes driven into the ground. One grounds to cable sheath only, while four others connect to cable sheath in addition to the other grounds.

Outside Grounds

Very few of the companies ground their neutral intentionally outside substations, though some ground to junction box castings. Some are accidentally grounded to a greater or less extent by the use of bare or poorly insulated neutral copper. Only one company makes deliberate metallic connection with the street railway return.

Relative Size of Neutrals

The general arrangement of the neutral feeders is what is known as the "tree neutral," that is, there is a heavy trunk neutral near the substation and from this lighter branches radiate,

all being connected to the main neutrals, usually in each manhole or junction box. The size of the "trunk" at the substation averages 18 per cent of the total positive or negative feeder copper.

Relative Weight of Neutrals

The average distribution of the total weight of copper in the distributing systems of the several companies is:

Feeders	Positive and Negative	56.5%
Feeders	Neutral	7.1%
Mains	Positive and Negative	25.2%
Mains	Neutral	11.1%
Neutral Feeders	Percentage of one outside	25.2%
Neutral Mains	Percentage of one outside	88.5%
Total Neutral	Percentage of total copper	18.2%

The above figures are partly estimated, as two companies could not give exact detail.

Size of Neutral Mains

Three companies use the same size cable for main neutrals as for the outside wires, the others running from 33 per cent to 60 per cent.

Type of Cable Used for Neutrals

Three companies use insulated, lead covered cable for feeder and main neutrals, two use scrap or low insulation cable, leaded, and two use weatherproof, rubber braided or bare cable.

Amount of Unbalanced Installation Permitted

All companies restrict the capacity of apparatus which they permit to be connected on one side of the system, the amount varying from one-half to two horse power. This restriction must be nominal, in some cases at least, as one company carries a battery charging plant producing unbalances as high as 300 amperes. In general the local unbalances largely compensate one another, the companies reporting that even in the large substations the actual unbalances which have to be compensated rarely exceed two or three hundred amperes.

In some cases where trouble has been experienced with heavy unbalances due to the customer's carelessness in balancing up loads on the two legs of the system, the use of an automatic circuit breaker tripping at a predetermined unbalanced current

has been found helpful. This remedy, however, is somewhat drastic and should be employed only as a last resort as a means of protecting other customers on the line from low voltage.

Trouble Due to Foreign Currents on Neutral

Most of the companies have had no trouble from this source, though one has had trouble in the past, and another finds it necessary to keep the system neutral clear of the cable sheaths which normally carry considerable stray railway current.

Battery Capacity

At times of very severe ground on one side of the system, the unbalanced current will greatly exceed the capacity of the balancer set, and the battery will be obliged to care for it. The reported battery capacities at the one hour rate average 27 per cent of the total maximum load, though one company has 55 per cent.

Conclusion

In general it would appear that the systems are very similarly constituted and operated, the differences being due largely to variations in local conditions. The following suggestions for reduction in investment and operating costs might be studied by the individual companies, though possibly not practicable because of unknown local conditions.

(1) The use of a tap from the transformer windings to establish the neutral instead of balancer sets with their constant losses, first cost and cost of maintenance. It is not necessary to have taps from all the converter sets; two machines in each substation (in order to insure continuity of service) have been found by actual test to be sufficient.

(2) As four of the companies operate satisfactorily with main neutrals only 50 or 60 per cent of one outside leg, it seems likely that the others could do so, effecting a considerable saving in cable cost.

GENERAL PRACTICE IN INSTALLING AND OPERATING UNDERGROUND STREET LIGHTING CIRCUITS

The practice of the central station companies in the installation and maintenance of underground street lighting circuits may be summarized as follows:

Series lighting circuits are used most extensively by all companies, except one, which has a preponderance of multiple type lamps. Arc lamps, mostly magnetite, are still widely used by 70 per cent of the companies, although several report that they are gradually replacing arcs with incandescent lamps. The 6.6 ampere was the most common current value, both for alternating current and direct current circuits. Few companies were using more than one lamp per pole, but the height of same above the street level varied between wide limits, 9 to 30 feet, with 18 to 20 feet the most common height. Lamp sizes also varied over a wide range, from 40 up to 750 watt, gas filled type.

The cable used for lamp connections is mostly No. 6 and No. 8 single conductor, lead covered rubber insulation being in somewhat more extensive use than paper insulation. Several companies make use of multiple conductor to the center of distribution and only one company is using two conductor cable exclusively. Thickness of rubber insulation goes as high as 7/32 in. with 30 per cent para for 8000 volts, while that of paper did not exceed 7/32 for single conductor cable and 7000 volts working pressure. Cable is almost universally installed in conduit, only one company having an extensive installation of cable laid directly in the earth.

In making cable connections at the base of the pole, 50 per cent of the companies make use of some kind of special fitting for terminating the cable leads. From this fitting, rubber and braid wire, having insulation equivalent to underground cable, is extended to the lamp socket at the top of pole. Two companies report carrying the lead cable right up to the top of the pole and making connections there to lamp base, either directly or by means of short flexible rubber and weatherproof leads. In making up splices in cable or between cable and pole wires, rubber tape is most commonly used, though paper tape is frequently employed. One company, using cable with varnished cambric insulation, uses paper tape in wrapping the joints. All companies but one fill lead sleeves with some kind of sleeve compound, and 50 per cent report that they do not allow splices in ducts or between poles, except in manholes.

All companies, with one exception which has buried cable, bond the lead sheaths of street lighting cables to other cables

and underground structures, primarily for preventing electrolysis, and three companies bond the lead sheath to the pole bases for safety to pedestrians against possible high potential charge on poles. A few companies are using insulating transformers or so-called "safety coils" with grounded secondaries to serve a few lamps on bridges, viaducts, iron structures, or in places where the street lighting cable parallels the structure for any great distance and where there is danger of the structure becoming charged to high potential due to a faulty cable.

Practically all series circuits are operated ungrounded and the practice of making daily tests for grounds is universal. One company reports making hourly tests during the off-burning period. In locating grounds or faults on street lighting cables, 50 per cent of the companies make use of a signal current and exploring coil method, while the other 50 per cent report different schemes of breaking into the circuit at the various poles and making tests from pole to pole, or pole to station.

JUNKING CABLE

In view of the large amount of wire and cable that finds its way to the scrap pile, particularly with large companies, the disposition of such at the best market values becomes a matter worthy of consideration by the central station man. The too common practice of selling mixed lots of junk, where gross weight only, and not the weight of the component parts, is known, should be discouraged as far as possible.

Several companies have devised special apparatus for reducing all insulated wires and cables received from the various jobs to the constituent metals, and in such form as can be handled most conveniently.

The apparatus consists of a power cutting machine for cutting cable to standard three-foot lengths; a power stripper for removing the lead sheath; a furnace for burning off insulation; and a baling machine for tamping the wire into dense and convenient sized bundles. The power cutter illustrated in Fig. 9 consists of a heavy punch press (8-in. stroke) fitted with a special shearing cutter which cuts the cable into comparatively short lengths.

Fig. 10 shows a motor driven cable stripping machine with

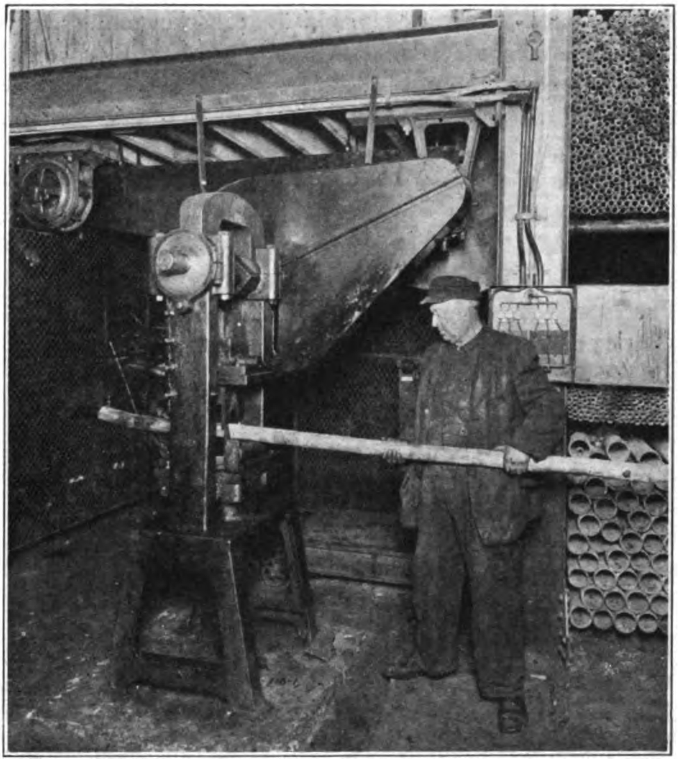

Fig 9—Power Cutting Machine

two circular steel knives which can be adjusted for cutting various sizes of cable, the feed being maintained by the double row of teeth which grip the lead and force the cable past the cutting knives.

After stripping off the lead the insulated wire is placed in a special furnace and the insulating material is burned off, care being exercised in the control of the draft to prevent excessive oxidation.

In some cases a baling equipment is employed to make up the scrap copper into bales of convenient size for handling.

The use of stripping machines has resulted in very substantial savings for companies which dispose of very large amounts of scrap yearly, as metal salvaged by this means brings about 80 per cent of the market price for new metal.

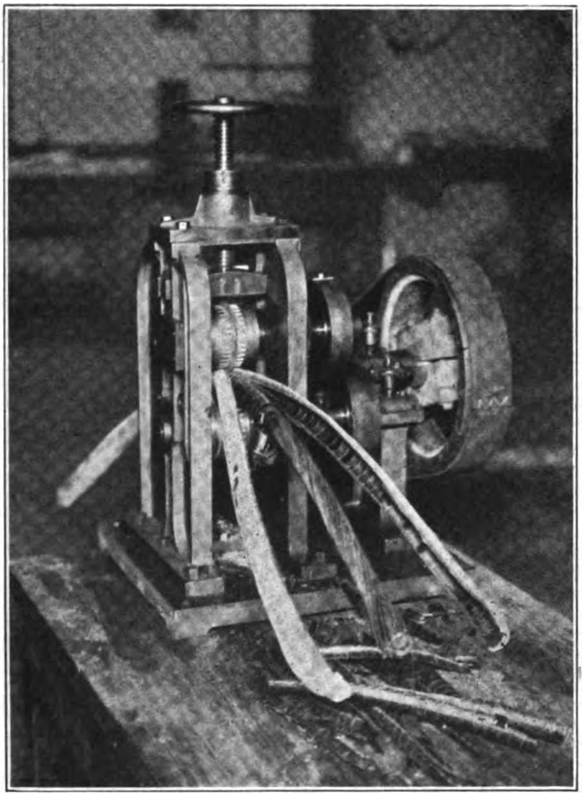

Fig 10—Motor Driven Cable Stripping Machine

Among the smaller companies the economy of mechanical devices is open to question, as it may be found that the total recovery cost per ton under this method will be too high on account of the relatively small amount of scrap handled during the year.

TRANSFORMER PRIMARY CUTOUTS

Nine member companies have underground transformer installations and of these four do not fuse the primary, as they believe there is no inexpensive and satisfactory cutout on the market at the present time.

With one exception, all companies which have used the enclosed fuse type report this equipment a failure, as more ser-

vice interruptions have been experienced where it has been used than where the transformers were connected in without fuses.

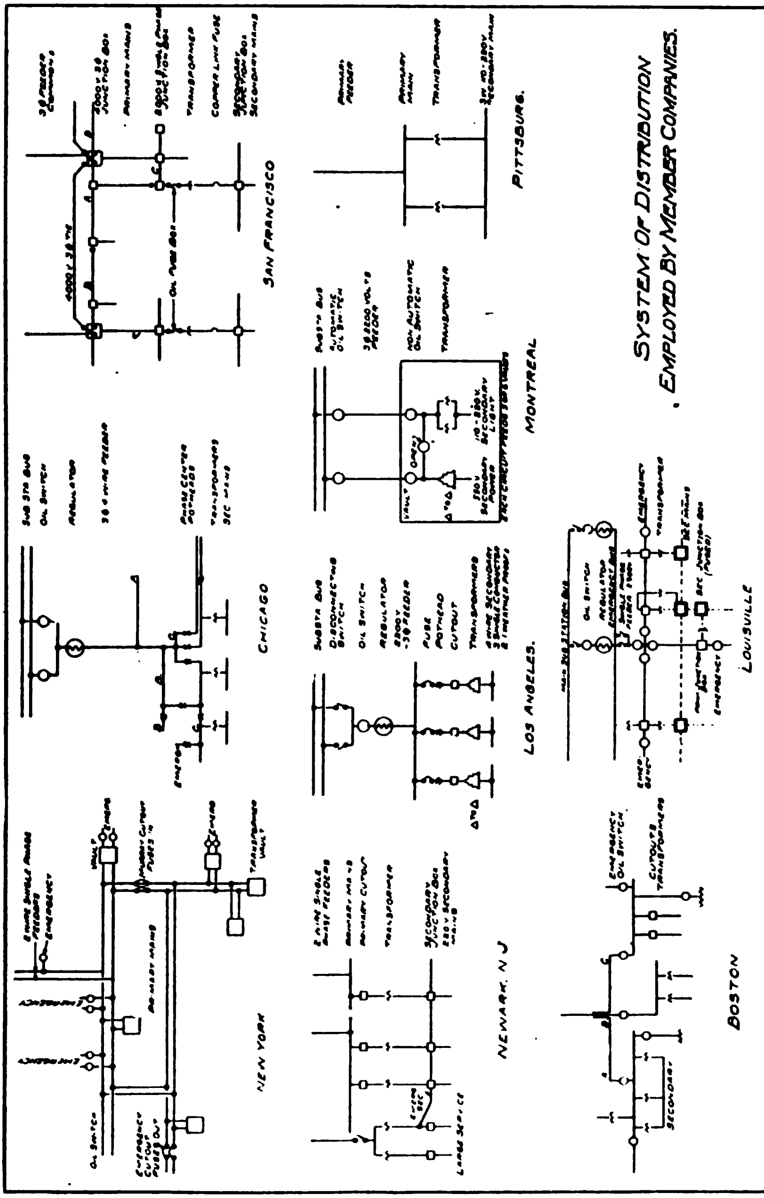

FIG 11

A primary cutout is installed for the purpose of protecting the service in case the transformer fails, and not to protect the transformer against overloads. The percentage of failures of transformers is considerably under 1 per cent per year, and consequently unless manufacturers can produce a cutout which has as good a service record as the transformer itself, operating companies will consider the cutout a hazard to the system instead of a protective device.

However, the companies which have condemned the enclosed fuse type of cutout are experimenting with oil-submerged and other types of fuses, and the development of a cheap and reliable cutout offers an attractive field of endeavor for the inventor.

One line diagrams of the distribution systems employed by the various companies are shown in Fig. 11.

SPECIAL DEVICES AND METHODS

Pneumatic Cutting Tools

While only two companies report the use of pneumatic cutting tools for removing pavements preparatory to conduit installation, very satisfactory results have been obtained and it is probable that this class of tools will come into more general favor.

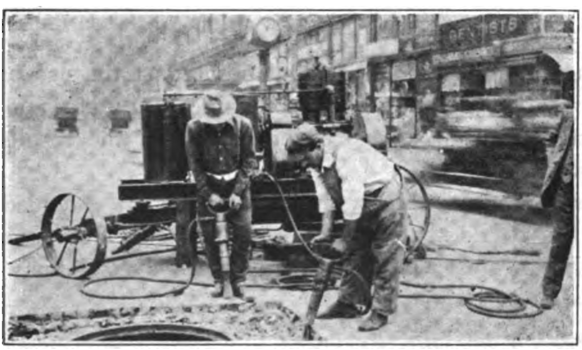

FIG 12—POWER CUTTING TOOLS

The outfit as illustrated in Fig. 12 and Fig. 13 consists of a 6 ft. by 6 ft. duplex air compressor driven by a 15 horse power

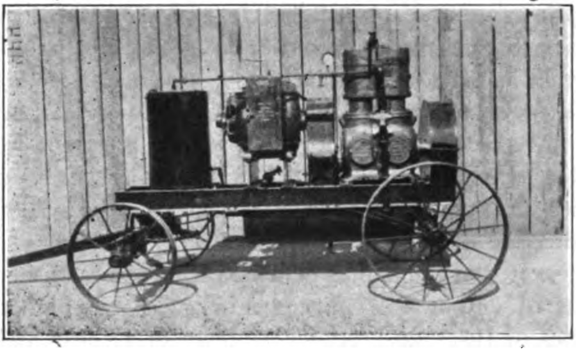

FIG 13—MOTOR DRIVEN COMPRESSOR MOUNTED ON TRAILER

electric motor, this equipment, as well as the cooling water tank, being mounted on a trailer.

The tool is similar in construction to the ordinary air hammer, the hammer being replaced by a socket into which the cutter or gad is inserted. The compressor outfit shown in the illustration is of sufficient capacity to operate two cutters working on hard pavement and three on fairly soft concrete or asphalt.

The use of the pneumatic equipment is not only safer than the old method, but in addition reduces tool breakage and cuts the cost of street opening to one-third of that which obtained formerly.

Concrete Mixers

Practically all member companies report the use of power-driven concrete mixers. Some companies use mixers on all conduit installations of any size and state that the results justify their use.

The Chicago Company, however, after an extended investigation, has found that the power-driven concrete mixer is not economical on jobs where less than twenty-five or thirty men are employed.

Kerosene Torches and Furnaces

Kerosene torches and furnaces appear to have passed through the experimental stage and are coming into general use. A number of companies are changing over from gasoline to kerosene, and the Committee recommends the change from the

standpoint of both safety and economy. The names of companies manufacturing reliable kerosene furnaces and torches will be furnished upon application to the Chairman.

Manhole Pumps

The Chicago Company reports the development of a very satisfactory portable outfit for quickly pumping out manholes. The apparatus consists of a well-known rowboat motor, the propeller being replaced by a small high speed pump.

The complete outfit weighs only 125 pounds, but can handle about four times the water handled by the old type diaphragm pumps, and for this reason should recommend itself to member companies as a very desirable labor saving device.

Cable Grips

All companies use the cable grip in one form or another, but as the use of larger diameter cables is general, the attention of member companies is called to the cable pulling eye illustrated in Fig. 14.

Fig 14—Cable Pulling Eye

This grip is used where the bore of the duct is only slightly greater than the cable diameter, leaving insufficient clearance for the usual form of wire grip. The eye is made of ⅝-inch round steel and is connected to the cable by stripping back the lead and insulation about 7 inches, wrapping the conductors securely around the shaft and soldering them fast.

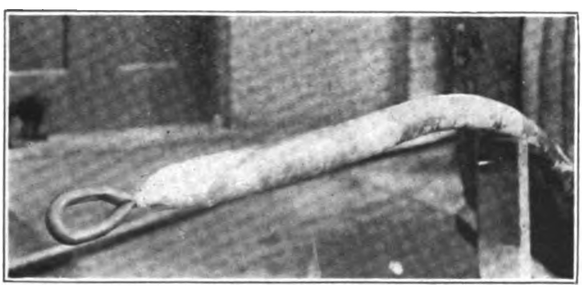

Fig 15—Cable Eye Connected and Joint Wiped

The lead sheath is then bent back into its original position and wiped with solder to make a smooth and moisture proof joint. The cable ready for attachment to the draw rope is shown in Fig. 15.

Trenching Equipment

None of the member companies is employing trenching machines for conduit construction, chiefly because their systems are located in congested areas where the use of a machine is out of the question on account of the presence of numerous obstructions.

Backfilling machines and power tampers are used very little, but it would seem that there is a fairly good field for the power tamper of the pneumatic type, particularly among companies which make use of the pneumatic cutting devices previously described.

Split Core Testing Transformer

One company employs a split core cable-testing transformer

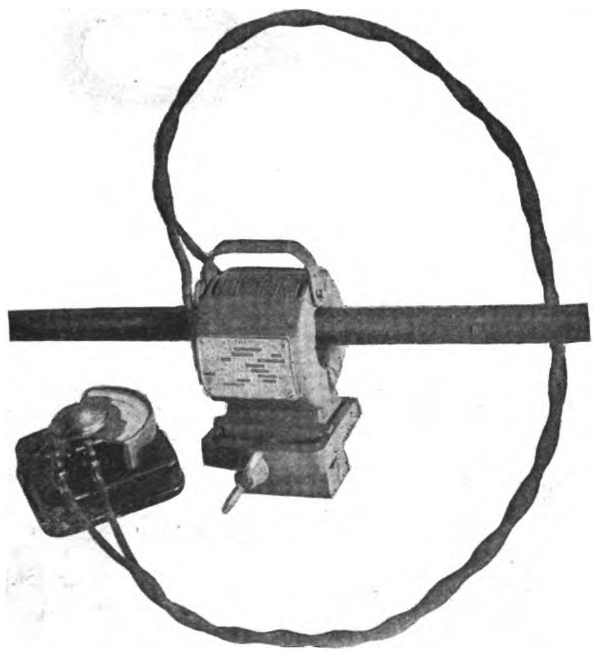

FIG 16—SPLIT CORE TESTING TRANSFORMER

which is used for the purpose of checking the load on single con ductor cables, particularly transformer loads. The instrument which is shown in Fig. 16, consists of a special transformer having a hinged magnetic circuit and a standard portable ammeter. Flexible duplex leads are supplied with each set, of sufficient length so that the transformer can be clamped in position around the conductor and the ammeter removed to a convenient place for reading. The instrument is used on the subway system for the purpose of checking transformer loads and determining whether each transformer is carrying its share of the load. Occasions frequently arise for using this set in determining loads on the various sections of the distribution network, where it has been found particularly valuable. The transformer will maintain within commercial limits its ratio accuracy from 10 per cent to 125 per cent load.

Respectfully submitted,

E B Meyer, *Chairman*
H B Alverson
W H Cole
L L Elden
L A Herdt
F B Lewis
L T Merwin
A A Meyer
H N Muller
J B Noe
R C Powell
W E Richards
F E Ricketts
D W Roper
L S Streng

APPENDIX A

Topical Index of Reports of the Committee on Underground Construction and Electrolysis

1911-1919

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*Page numbers for 1918 refer to bound Proceedings, no advance papers being issued that year.

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SUBWAY AND CABLE WORK

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"	36-37	Cable grips.
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"	37	Power tampers.
"	37	Back-filling machines.
"	36	Power pumps.
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1917—Pg.	31	Proposed diagram to give lighter and cheaper cable with better distribution of dielectric stresses.
1919— "	8-14	Specification form dealing with rosin oil and mineral oil compounds.

(2) Rubber

1913—Pg.	31	Detail specification of Boston Edison Company.
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Street Lighting Sytems—U. G.

1919		General practice—Types of cable used.

Subway Construction and Maintenance

1912—Pg.	8-15	Manhole construction—Costs. Duct arrangement. Tabulation of practice.
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1915— "	9	Manholes—Ventilation and maintenance.
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1916— "	21-24	Building cable tunnels.
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"	42	Spacing block for aligning ducts in manholes.

Tagging and Numbering Cables

1912—Pg.	7	Material and indications.
1913— "	25	Use of lead tags.
1916— "	53-57	Material of tags—Numbering schemes.

Mr. Ballard: This report seems to be unusually comprehensive, and will, no doubt, be productive of snappy discussion. I must go to another meeting for about half an hour, and I am going to ask Mr. Meyer, in the absence of Mr. Davidson, the Vice-Chairman, if he will occupy the Chair and conduct this discussion and sum it up. By that time I will be back.

(Mr. Meyer thereupon took the Chair.)

Mr. Meyer: Gentlemen, as you have heard, the report is now open for discussion. We hope that you are all prepared to say something. The Committee, of course, cannot carry on its work in a very profitable way without having the members suggest new ideas and give their experiences.

A. A. Meyer, Detroit: Mr. Chairman and Gentlemen, I would like to discuss joint filling compounds and give you the benefit of our experience in Detroit with respect to the use of paraffin and other compounds. To give you an idea of the extent of our experience, I might say that we have at the present time about 273 miles of 24,000 volt cable, all installed underground and comprising 4,500 joints in round numbers. Some of this cable was installed in 1907 and for several years afterward our joint failures were comparatively few. During the last two or three years we installed each year about 50 miles of cable, requiring the making of many joints. Our early trained splicers were good splicers, but not as good teachers to the additional force of splicers required by the increased amount of splicing work. This wasn't realized until joint failures became too numerous. It then became necessary to write a detailed specification and establish a school for splicers; not to teach new methods but to explain in detail our standard method and to point out the important factors affecting the life of a joint and also to make sure that the ideas were fully comprehended.

It was in March of 1917 that the written specifications were introduced and the school started, and since that time we have made up 1,515 joints. Of these, only two joints have failed—amounting to 1-10 of one per cent of the joints made, or equivalent to 2.2 joint failures per 100 miles of cable. These two failures occurred shortly after the start of our campaign and were found to show evidence of careless workmanship, for which the

splicers were criticised. The specifications referred to above included the use of paraffin, because at that time we had no direct evidence that the paraffin was at fault. The fact that since March, 1917, we have lost only two joints out of 1,515 would still uphold paraffin and also the statement in the Committee's report on page 25 that paraffin is a satisfactory joint filler if extreme care is used in making up the joints.

Although our records for the last three years show a comparatively large percentage of joint failures, these, with the exception of the two mentioned, were old joints made previous to March, 1917. We began to realize that our high tension cable system contained a lot of poorly made joints which must be either rebuilt or improved in some manner. It was decided to drain out the paraffin and replace it with some kind of the known black compounds. To date 335 joints, which according to our records were suspected of being faulty, have been drained of the paraffin and refilled with a black compound, and not one of these refilled joints has failed. The work of refilling is being continued as fast as conditions will permit, and will probably cover all of the suspicious joints.

We examined a large number of old made joints and found that the paraffin fill within was not in very good condition. Large voids were frequently found, particularly in the interior between the phase conductors where voids were most undesirable, apparently due to the large shrinkage of paraffin in cooling. Dielectric tests were made with new paraffin as well as old paraffin taken from a joint and the results differed widely. Laboratory tests were conducted with various kinds of compounds in regard to their suitability for joint filling, and our conclusions were that there were several equally good compounds for filling joints and that all of them were better than paraffin.

E. B. Meyer: We should be glad to hear from any one else in the room who would like to say something on this subject.

A. P. Thoms, Chicago, Ill.: The report indicates that the subject matter has been well chosen by the Committee as each topic is one with which operating companies or the manufacturers are wrestling, and it is therefore sometimes difficult to arrive at definite conclusions.

Dielectric Losses in Cables

The Committee states that it is not prepared to give its unqualified approval to the use of mineral oil compounds to the exclusion of all others.

I take it for granted that it is not the Committee's intention that operating companies, in drawing up cable specifications, should restrict the manufacturer to too great an extent in the choice of insulating materials, as other compounds may be discovered eventually that will improve the dielectric strength of the cable; nor is it best to insert in the specifications conditions or tests that will result in only an added cost to the purchaser for insurance, as it is not likely that the manufacturer will change his standard method of making up cable.

The ultimate object of cable specifications, from the viewpoint of the operating company, is to obtain a cable that will carry the maximum number of amperes at the operating voltage and temperature. As the operating voltage is fixed, but the load, and consequently the temperature, varies, it might be advisable to lower the voltage test requirements, and make more severe the performance requirements incident to heating.

Cable Fault Locating

For those companies that still operate Edison tube systems, I would like to emphasize the importance of locating faults on Edison tubes with an interrupter and exploring coil. Where a company is compelled to break into expensive paving in order to make repairs, it cannot afford to neglect the use of apparatus that will cut down the expense to a minimum. Although the Chicago Company is eliminating its tube system as rapidly as possible, there still remains a considerable amount of Edison tubes in service. In former years a foreman with a gang spent from two days to a week making street openings to locate a fault by the cut and try method; but now we are able, after spending an hour or two exploring with a large triangle coil, to uncover the faulty tube in the first opening.

Selection of Duct Size

The Committee has come to the conclusion that 3½ inch ducts are sufficiently large to take care of future requirements. This means that we will depend upon manufacturers to make

three-conductor cable of much larger capacity than any cable now in operation, for in view of the increasing capacity of Prime Movers, Rotary Converters, etc., we surely are not going to limit line capacity to anything like seven or eight thousand kv-a. as laid down by the Committee. I understand that manufacturers can now turn out a 12,000 volt three-conductor sector cable of 600,000 c.m. with the 3-inch diameter limit. Large companies, therefore, will be warranted in gradually changing their entire transmission layout by adopting as standard the largest size cable it is possible to install in a 3½ inch duct for tie lines between generating stations and trunk lines to distribution centers. In this manner cable of smaller size will be released for utilization elsewhere as feeders from distribution centers and for minor power cables; moreover, as we double the size of the copper, we cut in half the mileage required and thus reduce, proportionally, the burn-outs that would otherwise occur with twice the mileage of smaller capacity cable.

E. B. Meyer: I notice that the program lists several names of people who are to discuss this report, and I will call upon Mr. Bentley.

R. O. Bentley, Newark, N. J.: I have read the report of the Committee on Underground Construction and Electrolysis with a great deal of interest. To prepare a report of this character requires a great deal of time and study and I compliment the Committee upon the thoroughness with which it has dealt with its subjects. My remarks will be confined principally to transmission cables and subway.

Subways

Operating companies do not as a rule install underground systems from choice or to improve service. They are usually forced to install them to meet local conditions. Their first cost is high, and where they are used for high voltage transmission, the maintenance is high. Cable failures that often cause long interruptions to service, owing to the nature of the repairs to be made, are more or less frequent. I would not criticize the methods that have been employed in the design and construction of these subway systems, as the engineers who designed them did

good work with a rather limited experience. Now that we have had several years to study the outcome of their efforts we should profit by them. Many central station loads have grown so rapidly since these subway systems were installed, that both duct lines and cables are loaded to their capacity, and the unfortunate feature is that the situation cannot be relieved by replacing the cables with cables having larger capacity, as the present ducts are not of sufficient size to receive them. In my opinion for future installations ducts not less than 4½ inches in diameter should be used, as they would have the following advantages: cables could be more readily installed or withdrawn, saving time, equipment, and labor; better ventilation would be obtained; cables could be larger, thus making better insulation possible; conductors could be larger, thus decreasing the number of cables, and cable joints could be made that could be drawn into the ducts, thus eliminating cable waste. As all of these advantages would be lasting, they would warrant the increased cost.

Manhole Spacing

I do not think enough attention has been given in the past to the uniform spacing of manholes, especially in transmission duct lines. In my opinion great care should be given to spacing them uniformly. It is true that manholes increase the cost of subway construction. However, if the operating companies had standardized on the spacing of manholes at, say 300 feet, there would have been so many advantages over the present arrangement of spacing them at distances of from 100 to 500 feet, that the cost of the extra manholes would have been justified. I am reminded of a transmission duct line with manhole spacings as follows: 107 feet, 296 feet, 381 feet, 379 feet, 179 feet, 156 feet, 59 feet, 367 feet, 117 feet, 299 feet, 402 feet, 488 feet, etc. Think what it means to carry a stock of cable to make replacements in a line of that kind. I feel reasonably certain that the waste cable that has been junked after making replacements in this line, would have paid for any additional manholes that might have been necessary to have made the spacing reasonably uniform.

There is also room for improvement in the manner of arranging cables in manholes, especially in transmission lines. I am of the opinion that portable non-combustible shelving could

be arranged in such a manner that it would not be necessary to cover the cables with cement. Cement covering is very satisfactory in protecting adjacent cables in the event of a failure; however, when it becomes necessary to remove the cement covering from three or four cables before the faulty cable can be made accessible for repairs, it would seem that a study for improvement would be worth while.

High Potential Testing

The custom of making a high potential test on repaired cables before again placing them in service seems to be quite general. It is not unusual to apply a potential 20 or 25 per cent higher than the operating potential of the cable. My opinion is that it is poor practice, and that faults are often created rather than detected. I have known of 13,000 volt cables failing two or three times within a short interval, after receiving an 18,000 volt test. It was said the test "took the bugs out of the cable"; I think it put them in. The test is made to determine whether the repair will stand the operating potential; if it will, what good reason is there for subjecting the entire cable to an abnormal potential? I am informed through your Committee that recent experiments indicate that it is possible to make a cable joint having approximately the same outside diameter as the cable. Several of these joints have been made and subjected to very severe tests, without a failure. With the assistance of one of your Committee we expect to make up a section of cable using this new method. We will then place the cable upon a reel so that it will be handled as new cable when being installed. It is our intention to place in service for 13,000 volt operation several sections made up in this manner. If the result we expect is attained, the cost of cable replacements as well as the cable carried in stock, can be reduced to a minimum, and it will not be necessary to purchase cable stripping machinery.

I would again commend the excellent work of your Committee and would assure it that it has not been my intention to offer adverse criticism, but simply to make a few suggestions and comments that may be worthy of consideration. (Applause.)

Mr. Meyer: Gentlemen, we have about twenty minutes more. I would be glad to hear from anyone else.

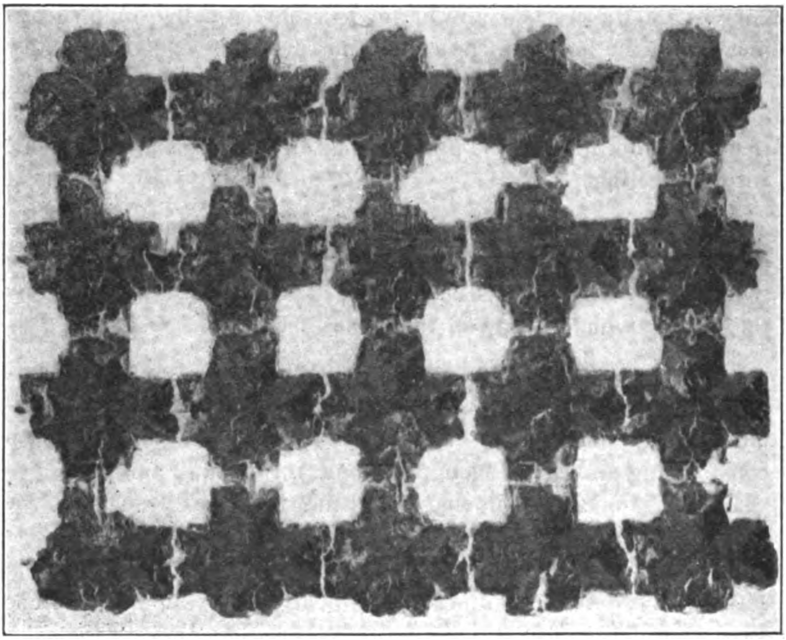
J. A. Brundige, New York City: I understand that some of the Eastern Power Companies have a method of periodically measuring the dielectric conditions of their cables while in service. This, I believe, consists of superimposing high-voltage direct current on the normal alternating current, and by some means measuring the losses in the cable, thus predicting when the cable will become too weak for safe operation. I do not know that any of the reports in the past have touched on that subject, and, if not, I think it might be profitable to discuss the matter at some future meeting.

F. T. Adams, Philadelphia: On page 214, speaking of covering the cables with cement, I would like to ask the Committee whether any thought has been given to the action on the lead by the plaster which is put on the cables?

J. W. Sylvester, Philadelphia: In his discussion Mr. Bentley touched upon the advisability of the development of portable shelf manholes. The Philadelphia Electric Company has been constructing and using such a manhole for the past ten or twleve years. It is octagonal in shape, and the shelves of soapstone, one inch thick, rest on angle irons, which are supported by sockets built into the wall, a construction which we have found quite satisfactory. As it is unnecessary to install any of the alberene stones until the installation of cables, the first cost of the construction of the manhole is materially cut down.

J. B. Noe, New York City: It might be interesting for me to amplify slightly that part of the committee report dealing with the protection of cables in manholes. The possibility of a bad manhole fire shutting down part, or even in some cases all, of the system, is now generally recognized, and most companies apply some form of fireproof covering to cables in manholes, the most generally approved mode of protection being a cement covering. The original method of application was to wrap a light rope spirally around the cable, and with this as a binder build up the required thickness of cement. This construction was wrong in principle, in that an inflammable material—rope—was used as part of a protection which was supposed to be fireproof. To overcome this objection, some companies are using instead of the

rope a material known as "metal lath." This is a ¾-inch square mesh of soft iron wires with a square of fire clay baked into each intersection, as shown in the accompanying figure. The metal



lath comes in long rolls but is cut into strips four inches wide and about five feet long, which strips are readily applied spirally to the cable to be covered, the ends being fastened with light twine. The cement adheres firmly to this material and is easily built up to the required thickness.

To test their relative heat resisting qualities, samples of cement protected cables with rope binder and with metal lath binder were subjected to very severe heat from an oil fire and also to a heavy direct current arc. The cable with the rope binder developed wide cracks in the cement, the rope was completely carbonized, the lead sheath melted and the paper belt of the cable badly charred. Though some slight cracks appeared in the cement on the metal lath samples, the lead did not melt and there was only a slight browning of the outer wraps of paper insulation.

As is stated in the report, one company has found difficulty in using a fault locator of the exploring coil type on cable protected by this material, owing to the shunting effect of the iron wire in the metal lath. In view of the marked superiority of this type of protection, it does not seem wise to condemn it for this cause, especially in view of the fact that large operating companies report that fully 75 per cent of high tension cable faults are located by the Murray Loop method, which is not affected by the presence of the metal lath. Even in the most extreme cases, it would only be necessary to remove the covering for a foot or less in a maximum of six manholes to locate a fault on a 20,000 foot feeder, and the cost of replacement would be insignificant.

It is possible to apply the cement direct to the cable without any binder, but our experience has been that owing to the difficulty in making it stick, the labor cost is higher, it is difficult to obtain an even thickness, and there are likely to be "pockets" on the lower side where the cement sags away from the cable. Also the mechanical strength is much less.

H. L. WALLAU, Cleveland: In Cleveland we have been using a cement covering on cheesecloth in preference to the metal lath.

This method reduces the amount of combustible material to a minimum. It consists in first wrapping the cable with a layer of cheesecloth. This cheesecloth, cut into rolls four inches in width, is wound on the cable just as ordinary friction tape is installed. On top of this a coating of cement and sand is plastered, from one-half to five-eighths of an inch in thickness, and on this is wound another strip of cheesecloth. Ordinary bank sand, in which there is some loam, is used and is mixed in two to one proportion with a very little water, to the consistency of very stiff mud. In winding this on with cheesecloth as above mentioned, the cloth is pulled tight, thus forcing the grout to ooze out between the meshes of the cloth, giving the cable a finished outer surface. Indeed, when the cement has thoroughly dried, the cloth cannot be seen. It is not advisable to go over this with a coating of neat cement, as this provides too fine a covering, and cracks will result.

The covering described above will not crack under any condition, and provides a surface of sufficient roughness to radiate

heat from the inside readily. It is evident that a cement coating of this thickness will perfectly protect the cable from any mechanical injury, and it is a fact that it will protect it from very intense heat from without.

Lately it has been found possible to eliminate the first wrapping of cheesecloth, winding the cement directly onto the cable.

Mr. Meyer: Gentlemen, we have about ten minutes more. Is there any one who wishes to discuss this report further?

H. Goodwin, Schenectady: One of the speakers referred to testing cables with high tension direct current. As far as I can recollect it, there is only one company which uses this method, and I am not sure whether it will continue using it. That is the United Company of New York, whose conditions are rather different from those in some other cities. In the first place, I believe it is used only on the 2200 volt system, and the 2200 volt system is all single conductor cable. The United Company used a constant-current arc machine, connecting one side of it to the ground and the other to one of the buses in the station. In this way using direct current, this whole system was raised up to any potential above ground desired. If there are any weak spots, these break down to ground but the generator being constant-current there is no seriously destructive short circuit. This method is evidently not possible with a multi-conductor cable.

The United Company did another thing, which is not the general practice at the present time, I think—certainly not where multi-conductor cable is used—it worked on the single conductor cable alive. For these reasons and the difference in conditions, I do not think that that method of testing has been generally adopted.

Mr. S. J. Lisberger, of San Francisco, summed up the general feeling of many engineers in regard to such tests, when he said, "We don't believe in hitting a man over the head with a club to see whether his cranium is sound."

Mr. Meyer: We have a little time left, gentlemen. Is there any further discussion on this report?

W. A. La Due, Jersey City, N. J.: I want to compliment the

Committee on this paper and to state that I think the field for continued effort by this Committee in the future consists in the study of a new manhole in which it will not be necessary to wrap the cables with any fire protection material. There are several schemes in practice whereby cables can be protected from communicating the arc of a cable breakdown to an adjoining cable. I am much pleased to know that the Philadelphia Electric Company is using concrete or soapstone shelves in its manholes which possibly does away with any wrapping and affords their Maintenance Department opportunity of making proper tests with a portable fault locator.

Inasmuch as it is almost impossible to create standard lengths of cable sections, I would suggest the use of a 4½-inch duct, particularly for transmission purposes. In a 4½-inch duct line with the use of 4-inch sleeves for joints, all cable could be pulled out and reclaimed with the exception of the small portion where the breakdown occurred. This would eliminate the excessive waste due to failures and the inability to reinstall portions of the section which appeared to be good. In conclusion, I am quite sure that this is a saving worth considering.

Mr. Meyer: Is there any other discussion on this report? Our time is limited. I am placed in a rather peculiar position here this afternoon, in having to read this report and then attempt to take the place of the Chairman and call upon the various members to discuss the paper. I will endeavor to sum up the discussion and close it so that we can continue with the rest of the program.

The remarks by Mr. A. A. Meyer in reference to the use of joint filling compounds, are very well taken, I think, and the Committee is particularly desirous of hearing from other companies on this subject. The difficulty the Committee has experienced in the past is that the questionnaires sent out did not bring the results expected, and if the members will only indicate to the Committee what their problems are, I think we can all benefit thereby. If a letter is sent to the Secretary, or to National Headquarters in New York, I am sure it will bring some results.

In reference to the several questions regarding the use of larger sized ducts, the Committee has seriously considered this

subject, and while in many cases it may seem desirable to use even 4½-inch ducts, it seems to be the opinion among the companies represented on this Committee that a 3½-inch duct is of ample size. However, there seems to be some disagreement, and undoubtedly the Committee would be glad to go over this subject at some future time and perhaps make other recommendations.

Regarding the question of building manhole shelves to provide for the better protection of cables, let me say that it has been tried by a number of companies, and while it works out very well in manholes used for transmission purposes, there seems to be difficulty in providing the proper shelving in manholes that are irregular in shape, and which are used for distribution cables and the housing of sub-surface equipment. It is possible, however, that something can be done along this line.

The question of the action of cement covering on lead cables was raised some years ago, and the Committee was informed at that time that one or two companies experienced some trouble, but, so far as I know, the investigation developed that the trouble experienced was not due so much to the application of the cement as to the cables being entirely submerged in water, which had an effect on the lead covering.

I think I have covered the principal points which were not answered in the discussion.

I again want to emphasize, however, before closing, that any one who has any problem at all in connection with underground work should get in touch with the Committee, because we want new ideas and we want to help the members in solving their problems.

I believe the next subject on the program is the presentation of the report of the Committee on Overhead Lines and Inductive Interference, Mr. A. E. Silver of the Electric Bond and Share Company, Chairman. I am going to ask Mr. Sproule to act as Chairman while Mr. Silver is presenting his report.

(Mr. Thomas Sproule thereupon took the Chair.)

Mr. Sproule: In the absence of the regular Presiding Officer, I will ask Mr. Silver to present his report of the Committee on Overhead Lines and Inductive Interference.

REPORT OF COMMITTEE ON OVERHEAD LINES AND INDUCTIVE INTERFERENCE

During the war period, your Committee did not attempt to hold meetings or conduct any active work outside of attending to current matters. It is only during the past few months that relaxation of the war stress has made it feasible to undertake resumption of more nearly normal activities. Any accomplishments of the industry in the field of the Committee's usual activities have been so largely of an abnormal nature that in this report the leading attention will be given to a review of the present status of certain more essential problems and to pointing out the course that would seem desirable in developing the future.

INDUCTIVE INTERFERENCE

The inductive interference situation has been rather inactive insofar as concerns the initiation of any new lines of activity coming to the attention of the Committee. Perhaps, the greatest single activity has centered about the California Joint Committee in the way of some further technical studies and attention to improving the former rules. This has led to the issuance of inductive interference rules in modified form as General Order No. 52 of the State Railroad Commission, effective August 1, 1918, superseding General Order No. 39.

This new order, while framed in a more cooperative spirit and otherwise indicating a better mutual understanding of the difficulties encountered, still appears to lack much of representing a satisfactory solution of the inductive interference problems of the telephone and power interests of California. It still provides comprehensive regulation of the kind, arrangement and methods of operation of power lines and apparatus, with relatively little attention given to the corresponding conditions of telephone lines and apparatus, or to the establishment of an equitable and economic balance between the corrective measures to be applied to the respective systems.

In Nebraska the State Railway Commission has incorporated inductive interference rules as a part of overhead line regula-

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Manuscript of this report was received April tenth.

tions, which it is understood will be issued formally at an early date, as more fully described later in this report. It is noteworthy that these rules, which will apply essentially to lines of 2300 volts and less, will constitute, it is believed, the first instance where a State Commission has felt called upon by legislative act to issue rules pertaining to inductive interference for lines of this voltage.

A new phase of the inductive interference problem is demanding attention, having arisen with the increasing use of the electric arc furnace, owing to its tendency to distort the wave form of a system from which it is supplied, its effect being essentially that of a huge arc lamp. Illustrative of this, mention is made of a case of inductive interference affecting the power system of a member company, the Iowa Heat, Light and Power Company, of Grinnell, Iowa. A furnace of approximately 300 kv-a. demand, supplied from a system fed by generators of relatively small aggregate capacity (approximately double the furnace demand), set up inductive disturbance from a feeder, which, however, while fed from the same generators, did not carry any of the power to the furnace. The disturbance resulted, it is said, from a distortion of the wave form of the generators due to the effect of the furnace.

Early this year, the Committee was called upon by the Subcommittee on Wave Shape Standards of the A.I.E.E. to assist in gathering data from actual practice on which to base values for a new wave shape factor called the "telephone interference factor," which it is proposed to incorporate in additional Institute standardization rules relating to permissible wave shape deviation for synchronous apparatus.

The purpose of these new rules, described in a paper by Mr. H. S. Osborne*, is to attack the inductive interference problem at the source of the disturbing element, by efforts to eliminate or restrict the harmful components from the wave shape characteristics of the machines which create them. It is stated that if in any 25 or 60 cycle power system no harmonics were

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*Paper by Mr. H. S. Osborne, appearing in the January, 1919, Proceedings of the A.I.E.E. entitled "Review of Work of the Sub-Committee on Wave Shape Standards of the Standards Committee." A supplementary memorandum appears on Page 59 of the February, 1919, Proceedings.

present, inductive interference, as commonly known, would not exist, and that it is the intent that the new rules shall encourage efforts so to improve apparatus design as to minimize, insofar as practicable within reasonable limits of economy, wave shape deviations that would occasion inductive interference.

The paper in question does not offer any definite quantitative estimate of the benefits that may result, nor does it make clear the extent to which it is the purpose of the A.I.E.E. rules to establish standards in the field of electric power and telephone service.

It is the purpose of this Committee to cooperate in this matter, so far as mutually advantageous, and at the time of writing (March, 1919) the subject is being given attention by the respective Committee Chairmen for the purpose of formulating a satisfactory plan of procedure to recommend for obtaining the information desired.

A paper recently published by Mr. J. A. Whitlow* contains a carefully prepared review of the legal status of inductive interference between power and telephone lines.

In those few recent specific cases of inductive interference of which the Committee has learned, a solution has been sought, by mutual desire, through cooperative effort. One case that might be mentioned was heard in June, 1918, before the State Corporation Commission of Virginia upon a complaint of telephone users that the service of a local telephone company was deficient and inadequate. In the hearing it was brought out that certain of the telephone circuits, which were of the ground return type, were being paralleled by a new power line which would render the telephone circuits inoperative, and further that a private agreement had been reached whereby the power company would reimburse the telephone company for a certain minor part of the expense of metallicizing the telephone circuits involved. The Commission in ruling that the telephone company should metallicize the circuits and giving its sanction to the private

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*Paper presented by Mr. J. A. Whitlow before the Student Section of the A.I.E.E. Section of the University of Missouri, December 3, 1917, entitled "The Legal Status of Interference Between Overhead Electric Power Transmission and Telephone Lines." This paper is reprinted in the June 1, 1918, Missouri Public Utilities Bulletin, and also in the June and July, 1918, issues of the "Telephone Engineer."

agreement as to division of expense, delivered the following opinion:

> "Interference with existing grounded telephone circuits by high power transmission lines will necessarily become an increasing problem as time goes by and as electric power continues to be developed. It is highly desirable for the good of the whole community that power companies be encouraged, with due regard always to the existing prior rights of the telephone enterprises. This Commission expects to pursue a policy accordingly, and will require, as occasion may arise, such reconstruction of telephone lines as will enable power companies to exist and operate without being forced to bear excessive financial burdens. It will be a matter for determination in each individual case as to that part of the expense of changes from grounded to metallic lines to be borne by power companies."

In general, it is believed that the tendency hitherto has been disproportionately toward segregating the disturbing influence rather than toward development of suitable methods of coordination, although of course there is no desire to question the desirability of keeping lines apart, other considerations being equal. Furthermore, in the recent efforts towards overhead line regulation, particularly those of California and Nebraska, there seems to be a tendency to favor telephone lines as against power lines in the use of highways. Any leaning in this direction is believed fundamentally unsound and detrimental to the public interest, as well as imposing unjustifiable hardships upon the power companies. The industrial and general development of the country is coming more and more to depend upon widespread and adequate supply of electrical power, which in turn involves increasing use of electric lines of the higher voltages, which are most likely to give rise to interference, particularly of the higher distribution voltages. Any undue expense and difficulties imposed upon the construction and extension of these lines can only result in delaying and hindering industrial development and general public prosperity.

Clearly, the general inductive interference situation requires continued and increasing cooperative efforts between the parties

at interest, both in the way of engineering analysis to gain a better mutual understanding of the contributing factors in all the apparatus concerned, and in so laying out and coordinating any extensions of lines or equipment as to guard against harmful disturbances. The indispensability to the public of adequate service of each class lends emphasis to the importance of this coordination, but in effecting it there is real danger of an undue share of the responsibility falling on the system which contributes the disturbing influence, an influence, however, which is harmful to no other than the peculiarly sensitive telephone apparatus. This is partly due to the power men's lack of knowledge of both sides of the question, which has naturally followed from the condition that it is in the telephone system, the system of the supersensitive facilities, where the disturbing effects are felt, which fact has been an effective incentive for telephone engineers to study thoroughly the power system side of the problem, while on the other hand, since the power system is not susceptible to any similar disturbance, the power engineers have lacked this direct incentive for close study of the telephone side. This effect is occasion for even greater apprehension when recognition is given to the fact that, as the art advances, the sensitiveness of telephone apparatus is constantly increasing.

The highly technical nature of the subject, as well as the lack of publicity of technical details of telephone apparatus, has also tended to discourage power engineers from attempting an understanding of the telephone company's side of the interference problem, while, on the other hand, the engineers of the American Telephone and Telegraph Company have been thoroughly alive to keeping posted on all the technical details of power apparatus and methods of use, and, furthermore, have collected much specific information of this kind from individual power systems. The natural result is that, in negotiating inductive interference problems, the outcome is likely to be unduly favorable to the telephone side.

Furthermore, member companies must keep constantly in mind the fact, so many times evident, of the disadvantage to the industry in any controversy from the lack of thoroughly coordinated effort due to its being composed of many individual companies, versus a strictly centralized control such as that of the

telephone industry, as coordinated and directed from the central office of the American Telephone and Telegraph Company. It is to counterbalance this handicap partially that in the matter of inductive interference the Committee stands ready to render every assistance possible and wishes to act as a medium for enabling the many companies to work together more effectively. To this end the Committee urges member companies to keep it thoroughly posted on any activities of this sort so that before conclusions are reached advantage may be taken of the experience of others and safeguards provided against establishing precedents likely to prove embarrassing to the industry in other localities.

An article by Mr. John B. Taylor containing a discussion of interest relating to the more technical aspect of some of the active inductive interference problems will be found appended to this report.

OVERHEAD LINE REGULATIONS

Owing to precedence of war emergency demands there has been very little attention, so far as the Committee has learned, on the part of State Public Utility Commissions to initiate the promulgating of overhead line regulations. However, in some States where such proceedings were already in progress, these have been continued and rules issued.

Among these are:

The Pennsylvania Public Service Commission has issued an order* regulating overhead line construction at crossings.

The Public Utilities Commission of Kansas has issued overhead line regulations.** These rules are in general based upon the 1916 Edition of the National Electrical Safety Code.

In Nebraska, it is learned, that pursuant to legislation enacted in 1915 and amended in 1917, "so that reasonable, safe and *efficient* operation of existing lines shall not be interfered with," a set of rules has been prepared under the direction of the State Railway Commission, and, following a formal hearing on March

* Pennsylvania Public Service Commission, General Order No. 3, "In the Matter of the Regulation of the Construction of the Crossing of the Wires of a Public Service Company Over or Under the Facilities of Another Public Service Company," effective February 27, 1917.

** Public Utilities Commission of Kansas, Docket No. 1944, "Rules Relating to Wire Construction," effective July 30, 1917.

5, 1919, it has been stated that they will be issued and made effective promptly. It is pertinent to note that the peculiar framing of the legislative act mentioned in effect allows freedom in the matter of location of signal lines, while location of the power lines is subject to approval by the Commission. The National Electrical Safety Code, 1916 edition, has been taken as the basis for the portion of these rules pertaining to safety.

The Public Utilities Commission of Connecticut has issued rules* covering joint use of wood poles. These rules are modeled in the main after the recommendations of the American Electric Railway Association for joint pole usage.

The Public Utilities Commission of Utah has issued an order, effective February 15, 1918, tentatively setting up the National Electrical Safety Code for the regulation of overhead line practice.

In the matter of the trial application of the National Electrical Safety Code, issued in tentative form in 1916 for "examination, trial and constructive criticism," it has been the purpose of the Committee to encourage conscientious effort by all member companies in trying out the Code in their regular operations; this in order that it may be more accurately measured against prevailing good practice and thereby data collected for assisting in the working out of any revisions which the Bureau of Standards may undertake prior to final issuance of the Code. Unfortunately due to all possible diversion of effort to the war emergency to the extent that the activities of the industry were in effect under Government direction and to the almost entire lack of construction activities other than of an emergency nature, it has thus far been possible to accomplish but very little in this direction.

JOINT USE OF POLES

Joint use of poles by power companies and telephone companies is of much concern to the industry for reasons of conservation and public convenience, and every reasonable effort should be made to further its general application along sound lines. It is of increased concern both because of the accentuated need

*Public Utilities Commission of Connecticut, Order D, Docket No. 1447, "Approving and Establishing Rules and Specifications Governing Joint Wood Pole Line Construction," effective April 1, 1917.

of economizing during the present situation of high construction costs and because of growing civic interest.

Prevailing telephone practices thus far have acted definitely to discourage extensive joint use, as they limit it to circuits not exceeding 5000 volts and make no suitable provision for meeting the condition of higher voltage circuits when required in the development of power company business. Nevertheless experience with joint use at the lower voltages supplemented by the experience of several companies with joint use at higher voltages, clearly indicates that the public and all other parties at interest can, in general, realize through this medium greater safety, convenience, and economy.

There is undoubtedly a very definite need for a more comprehensive and better balanced working plan for joint use, in order, in the public interest, to foster its broader application. Cooperative efforts of the power and telephone interests have been in progress for the past year or more at the instance of the Pennsylvania Electric Association, the aim being to prepare a more suitable form of joint use contract and specifications, intended as a help to its member companies in the matter of joint use practice. In view of this and of the uncertainty as to what attention may be given to the subject in the final issue of the National Electrical Safety Code, the Committee has believed it inopportune to undertake any immediate efforts along this line. It should not be overlooked that the inductive interference problem enters as an important influence in retarding advancement of the joint use situation.

STANDARDIZATION OF LINE MATERIALS

Stimulated by the results accomplished by a committee of the War Department in the matter of standardization of overhead line materials for War Department uses, all as a part of the general activities of the War Industries Board to meet the overseas emergency needs by facilitating production and eliminating needless duplication of equipment and materials, the Committee believes that the line material lists of most central station companies offer opportunity for effective improvement through eliminations and simplification. To this end, the Committee is undertaking to prepare standard schedules for the more essential line materials, expecting to take advantage so far as

practicable of the work already done along this line by manufacturers and others in formulating these War Department standards.

MISCELLANEOUS MATTERS

Among the many war-time suggestions made by manufacturers for the purpose of facilitating production was a proposed new standard for cable stranding. This proposed standard is based upon utilizing a minimum number of strand sizes, and designating each cable in terms of the number and diameter of strands composing it, rather than in terms of the circular millage as at present. It is claimed that by thus reducing the number of sizes of wire strand, the problem of manufacturers' stocks will be much simplified and that the manufacturers, particularly those who do not draw their own wire, can make more prompt deliveries. Presumably also there should be some slight saving in cost. Objections are being offered to the proposed new standard on the ground that it will disturb established design practice and that inconvenience will result due to too large steps between cable sizes and unsuitable size of individual strands for certain classes of cables, and also that, due to different outside diameters, existing schedules of cable fittings will require modification. The Committee has undertaken to gather an opinion upon this recommended new cable stranding standard insofar as it affects practice in overhead distribution and transmission conductors.

In the matter of insulator depreciation, particularly in higher voltage usage, it is believed that this still prevails at an undesirably rapid rate, although so far as the Committee has been able to learn, there has been very little effort put forward during the war period to analyze the causes further. Renewed activity in the form of comprehensive insulator analysis and research is greatly needed, particularly in the matter of design and manufacture. The Committee is anxious to keep in touch with the experience on insulator performance and urges member companies to observe closely and keep a record of the results obtained from the different styles of insulators, particularly those of suspension type or more recent manufacture. The Committee will be glad to receive any such data.

In the matter of revision of the Overhead Line Handbook,

which the Committee has had in mind for some time, it has been considered preferable to await the outcome of changes in practice that may be attendant upon the final shaping up of the National Electrical Safety Code situation.

Respectfully submitted,

A E Silver, *Chairman*
R L Baker
Markham Cheever
R D Coombs
A A Dion
E D Edmonston
John B Fisken
H B Gear
R H Halpenny
T O Kennedy
T F Johnson
J C Martin
W E Mitchell
W T Morrison
B E Morrow
C R Oliver
C S Ruffner
Thomas Sproule
John B Taylor
W R Thompson
W K Vanderpoel
J E Woodbridge

Mr. Sproule: Will Mr. Taylor come forward and present his portion of this paper, please.

APPENDIX TO REPORT OF COMMITTEE ON OVERHEAD LINES AND INDUCTIVE INTERFERENCE

TELEPHONE DISTURBANCE BY INDUCTION

By John B Taylor

The Report of the Committee on Overhead Lines and Inductive Interference calls attention once more to the need of real cooperation between those engaged in the business of distributing electric power and those who have in their charge telephone communication over electrical circuits.

Nothing new has happened to modify the natural laws of electrostatic and electromagnetic induction. It is not practicable nor even possible for the transmission engineer to arrange circuits and conductors so as to avoid entirely surrounding "fields," i. e., electrical and magnetic conditions in space outside of the conductors.

Often it is equally impracticable and impossible for the telephone engineer so to locate his lines that they will be completely outside of the fields or space influenced by other electric lines.

The net result, well known to all electrical engineers, is that the "fields" cause electrical pressures and currents to be established "by induction" in the adjacent telephone lines and connected apparatus.

If there were not so great a difference between the electrical pressures and currents used in the transmission of power and those used in the telephonic transmission of speech, the avoidance of interference from the induced currents would be a comparatively simple matter. The telephone company, by properly arranging the two sides of its circuits and by transpositions of the conductors, as well as by other expedients, can establish a "balanced" condition which greatly reduces the magnitudes of the induced voltages and currents and hence the noise produced in the telephone receivers at the ends of the line. Similarly, as a further step, there is the possibility of setting up balanced or opposing fields in the power circuits by interchanging or transposing the line conductor positions, such transpositions

being obviously most efficient when properly coordinated with those established in the telephone circuits.

The sensibility of the telephone is, however, such that appreciable disturbing sounds may be heard due to the small currents which circulate as a result of the practical difficulties in setting up perfectly insulated and balanced telephone lines.

The problem thus becomes one of experience and compromise among many factors, viz.:—

1. How much "noise" should be tolerated by the user of the telephone?
2. How far can the telephone apparatus and lines be modified in the way of making them less sensitive to induction disturbance without unduly increasing the cost or limiting the service?
3. If on the telephone lines there is set up a phantom circuit which is more susceptible to induction, and hence more likely to be noisy, should this phantom circuit or the simple circuit be taken as criterion when asking a power company to help out by modifying its system?
4. If the telephone makes use of "grounded neutrals" on its own system, should this be overlooked when scrutinizing the effect of a grounded neutral on the power system?
5. In power systems operating with grounded neutrals, how far, in the determination of the number, location and character of the ground connections, should the power companies sacrifice their own requirements as to reliability and continuity of service to meet the wishes of the telephone companies?
6. If the normal development of electrical apparatus results in wave shapes with components likely to occasion disturbance in telephone circuits, how far should designers be limited and manufacturing economies be foregone to meet a wave shape standard restricting such components?
7. Should a power company refuse to take on a customer if the current demanded by the commercial process reacts on the system to alter the wave shape in a manner likely to occasion inductive interference?
8. Does the present general practice in the design and opera-

tion of the telephone lines and equipment, which in the main has been established under earlier conditions when external inductive interference was not a serious problem, represent the best adaptation practicable to modern conditions when the industrial development of the country demands an ever-increasing use of high voltage lines?

Many more questions similar to the items in the above list might be set down, but these are enough to show the complexity of the situation and the need of mutual understanding on the part of the power interests, telephone interests and the public. The same three parties must cooperate if the Public Service regulations and Commission rulings are to be in fact, as well as in theory, expressions of the best public interest.

We may start with the assumption that the power companies wish, within practicable economic limits, to construct and operate transmission and distribution systems in a manner to make the minimum disturbance on adjacent telephone lines; that they stand ready to consider specially selected or modified apparatus, connections and construction, all adapted to relieve the interference situation. They feel justified, however, in asking that assurance be given that before being called upon for expensive and restrictive expedients in their systems, the telephone companies have first taken all reasonable measures on their own systems to remedy the conditions of disturbance, or, if no such direct measures be effective, that they are at the same time cooperating in similar measures, and further that the burden of making changes or incurring special expense for improvement of telephone service be equitably distributed.

In general, it is more economical and, in other ways, more satisfactory, where parallels are anticipated, to avoid interference by proper initial construction, rather than to make substitutions and changes after starting up and discovering that an interference situation exists which must be given consideration. In order to predict and avoid, dependence must be placed on the knowledge of characteristics and constants of both power and telephone apparatus and lines. If the accumulated technical information from investigations and tests is supplemented by knowledge of the service conditions for many typical cases where power lines and telephone lines operate in the same district,

including cases both where harmful interference has been occasioned and where it has not, there will be available some basis for avoiding and correcting disturbance. Up to the present time, the pertinent features of generators, transformers, switches, lightning arresters, line construction, etc., are generally known through published descriptions and technical discussions. The corresponding pertinent features of telephone apparatus, systems of connection, line construction and service conditions are not in the same way available for consideration and discussion. With the best of intentions, the power man cannot be expected to take as much interest in relieving a situation where he is working more or less blindly as he would if supplied with a more definite and understandable statement of troubles existing and steps taken by both parties to improve matters, and, finally, a statement of the "before" and "after" disturbance in terms of standard or well-recognized measure.

It is to be hoped that eventually an increasing fund of knowledge and experience will enable establishment of certain generally recognized standards of practice whereby power systems, following approved methods of design and construction of generators, apparatus and lines, may be considered to have done all that can reasonably be required except in special cases of long or severe parallels, and whereby telephone systems may be expected to be able to provide satisfactorily against interference except in such special cases, and further whereby general principles governing methods to be followed in such special case may be outlined. Unfortunately, however, the state of the art, or at least of the general knowledge of the art, does not make feasible the building up in the immediate present of such standards of practice.

In particular there is available on the telephone situation no body of information sufficient for establishing what is reasonable and permissible in setting up standards. There is apparently more activity in the direction of making limits and specifications for power apparatus, line construction and connections than there is in establishing a scale of similar preventive measures which must be carried out in the telephone system as an antecedent or concomitant condition to calling into effect the measures specified for the power system. As it is obvious that

better progress can be made if both sides of the situation are presented and discussed at the same time and in the same manner, there is good reason for urging that all who have quantitative as well as qualitative information see that it is made available to others who are interested.

In a case of interference, the telephone engineers will ask or obtain information on:—wave shape of generators and other synchronous machinery, connections of transformers, magnetic density of transformers, types of switches, lightning arresters, line construction, line transpositions, presence or absence of single-phase feeders or extensions, presence of grounded neutral at one or more points, etc.

Some of the corresponding information for the telephone system which should be brought out in the same investigation would be:—number and destination of exposed circuits, nature of disturbance experienced and amount of noise (in terms of "noise standard"), balance of circuits (both as to conductor resistance and insulation resistance), description of circuit such as long distance, toll, local, ordinary or phantom, superposed telegraph, use of loading coils, use of repeaters, use of balanced or unbalanced grounds on telephone systems, typical diagrams of the different classes of circuits, etc.

After changes have been made with a view to reducing the disturbance, record should be made again of the noise and also of the insulation resistance and other features affecting balance.

As to the possibilities of radical changes in the inductive problem, little can be suggested except the recent announcement by the American Telephone & Telegraph Company of the development and limited use of a system of multiplex telephony whereby a single pair of wires serves for carrying four or five independent conversations. A detailed description of this system has not yet been given to any of the technical societies or to the technical press, but, from the brief and popular accounts, it might be concluded that since this multiplex system makes use of considerably higher frequencies than the frequencies of speech and also higher than the more important harmonics accompanying commercial transmission frequencies, the multiplex system should be more free from noise disturbances. This multiplex development will naturally be watched with close interest

by all, and it is to be hoped that before long there will be available more definite information as to its relation to the inductive interference problem.

MR. TAYLOR: I have endeavored to point out that there are many points of similarity between a power transmission system and a telephone line, and in the problem of their relation, which seems to be mutual to the extent that one bothers the other and the other does not bother the one in the same way. The electrical and magnetic features of the power apparatus and line are generally familiar through presentation and open discussion in the electrical societies, while the corresponding electric features of the line and the electric and magnetic features of the telephone apparatus are not generally so well known to the electric profession at large. As Mr. Silver intimated in his presentation, the result has been that there has been an incentive for telephone engineers to know, naturally, their own apparatus, and also to investigate and collect data on the power system.

Now, of course, it is desirable, in attacking any problem, to be familiar with all the facts, and the power people have regarded the telephone line as a special thing apart, and since they are not familiar with the details, they are not given to asking specific and pertinent questions when one of these interference cases comes up. As a result of this, I think, in a majority of cases the Telephone Company merely says: "We are disturbed; we would like to have it made thus and so; change your transformer connections; change your grounds and put in other things here and there." I don't know that there has been any disposition on the part of the telephone people to take advantage of this fact. Nevertheless, there have been cases where power companies have been put to considerable trouble and expense to accommodate the telephone company, and little has been presented to show that all this effort has been productive of any real result. The thought that I have endeavored to express in this appendix is that the problem should be presented more evenly on both sides, so that when a given case comes up and the data are collected on the power line, the system of connections and the characteristics of the apparatus, at the same time the bill of com-

plaint, if we wish to call it that, will specify what the trouble is, not merely a statement, "we are bothered," because that is what it has heretofore been limited to in the main. That is, there is no reason why the Telephone Company should not, in addition to saying that it is bothered with a noise of a certain nature which ought to be done away with, give at least a general description, if not a specific description, of the noise, and state that this noise is of a certain amount.

Now, we have not any very definite noise unit. The Telephone Company has a noise unit, but this unit is not as generally familiar as it should be. Similarly, the power companies, most of them, have found it highly advantageous for continuity of service and reduction of breakdowns to ground their neutrals. In most cases the telephone interests think this gives them some trouble; but it is not so well known that telephone companies make use of grounds in their own systems for similar reasons, increasing and benefitting their service, so this should be brought out. It is only fair, when attacking a case, to endeavor to set up according to a proper, evenly balanced arrangement, the similar facts on both sides that should be brought forward, and they should be considered by every one interested who makes use of these facts.

Mr. Sproule: This report is now open for discussion, and I suggest that we discuss it in the order in which it has been presented, first taking up the question of inductive interference. I would like to hear from Mr. Gear.

H. B. Gear, Chicago: There are one or two points in this report that I feel should be further emphasized. With regard to this proposed establishment of a telephone interference factor, some of you may have seen in the January number of its *Proceedings,* the proposal by which the American Institute of Electrical Engineers proposes to establish such a standard. The telephone interference factor is a proposed standard based on the fact that the telephone is most sensitive to noises having a frequency in the vicinity of 800 to 1100 cycles. A mesh of resistance inductance and capacity is made up, the parts of which are so related that they have a circuit in which the instrument is connected which is sensitive at about 800 cycles. When this instrument is connected to the circuit, if there is any higher harmonic in

the voltage wave, it develops in this network at about that frequency, and the instrument will read much higher than if the voltage wave were clear of such harmonics. It is proposed by the use of such a telephone interference meter to pick out wave shapes that are bad and so establish a specification which can be applied in the manufacture of machines which will minimize telephone interference and protect the power company from buying machines that are likely to cause such trouble. The scheme, however, is still incomplete in that as yet there is no relation fixed between the reading of the interference factor meter and the amount of noise which any particular reading of that meter will make in a telephone receiver; and until the telephone company engineers who are proposing this standard present something definite as to what values of interference factor would be considered troublesome, we are more or less in the dark as to the proposition.

The readings which have been taken so far cover quite a wide range of interference factors, running from 11 up to 500, but it is impossible to say at present whether 500 is a dangerous reading or whether it has to go higher. The Overhead Lines Committee, however, is represented on the sub-committee of the A.I.E.E. which has this matter in hand and will not agree to any policy which will unduly increase the cost of generating machinery.

This illustrates, however, very clearly, the point which has been mentioned in the report, that the engineers of the Telephone Companies are watching this matter, studying it with every scientific facility at their command, and with the aid of the very best brains in the organization.

The Committee labors under the disadvantage of not having at its disposal experienced telephone engineers, and also of dealing with a disorganized group of member companies, many of which do not realize apparently that when they get a case of interference, there is a committee of the Association which can help them. As a result, they are at a serious disadvantage, because they are dealing with people who are experienced in such matters and know how to get what they want.

The thing I want to impress upon you is that if we are going

to get anywhere the Committee must be kept informed as to the cases which arise and allowed to cooperate in such cases.

The attitude of the telephone companies toward this matter, as I said, is naturally one of great concern. In most cases, however, they have been quite friendly about it, perhaps realizing that such a policy is most effective. Their attitude has been to cooperate with the power engineers as closely as possible and get all the information they could, and so try to work out their schemes with the benefit of the information that is available from both sides. However, we cannot lose sight of the fact that they are working for their own interests, and all the information that we may have occasion to give them will be used for their interests, and it is up to us to keep ourselves informed as to things about their business which may be of interest to us to know in making these settlements.

Mr. Sproule: Mr. Ballard has declined to take over the Chair, so I will have to preside over the meeting.

B. E. Morrow: The thoughts that Mr. Gear expressed I think are along the right lines. We had some practical experience in Michigan of difficulties due to inductive interference, and we made up a report, a copy of which I turned over to several members of the Committee. Mr. Morrison of our Committee has condensed the report, and I will ask him if he will be good enough to read the brief report.

W. T. Morrison, New York City: Mr. Morrow has asked me to cite a few of the cases pertaining to inductive interference and some of the remedies and some of the complaints of the telephone companies.

In Case No. 1, the transmission line voltage was 140,000 volts. The interference was with three Western Union telegraph wires, one of which operated as a grounded telephone circuit. The lines were parallel to each other for a distance of 30 miles. The distance between the centers of lines was 35 feet. The volts induced on the telephone line circuit were 2300. The resulting trouble on the telephone line was a fire which started in a telegraph office setting fire to wooden telephone switchboards. The remedies we tried were: no transpositions,

voltage induced on telephone circuits, 2300; two transpositions, voltage reduced to 500 volts; 8 transpositions, voltage reduced to 25 volts, Western Voltmeter to ground; 17 transpositions, current on telephone line still exceeded 6 milli-amperes, which is considered quite noisy by the telephone company. Resonant shunts were placed around the telephone relays, reducing the current, so that the relays could be operated, but not satisfactorily. The final outcome was that the telephone lines had to be moved further from the power lines. This was done at the joint expense of the power company and of the telephone company.

In Case No. 2, the transmission line voltage was 40,000 volts. The lines paralleled each other for several miles. The remedy applied was the transposition of power lines, which remedied the trouble on the telephone circuits.

In Case No. 3, the transmission line voltage was 140,000 volts. The lines paralleled each other for half a mile. The distance between the two lines was 60 feet. The distance between the centers of lines was 70 to 80 feet. That was in two parts, one part 60 feet, and the other 70 to 80 feet. The telephone company complaint was induction and possibility of failure of towers, which would cause physical contact, even though lines were placed on opposite sides of the highway. The telephone company complained of considerable noise. The remedy applied was moving the telephone line at the joint expense of the power company and of the telephone company.

Case No. 4 was somewhat similar: transmission line voltage 140,000 volts. The lines paralleled each other, in one section two miles and in the other section three and a half miles. The distance between the centers of lines in the first section was 58 feet and in the second section 40 feet. The power lines were on a private right of way and the telephone lines on a railroad right of way. The power company had no knowledge that the telephone company had secured a permit to build on the railroad's right of way. The remedy applied was moving the telephone line at the joint expense of the power company and of the telephone company. One point that might be mentioned is the extra expense of making these changes afterwards, and the pos-

sibility of avoiding this through the original selection of routes, even involving an additional expense.

In Case No. 5, the transmission line voltage is not indicated. The lines paralleled each other 22 miles. The power lines were practically over the telephone company wires. The telephone company's complaint was the menace due to induction and possible contact. The remedy applied was moving the telephone lines to the railroad's right of way at the joint expense of the power company and of the telephone company.

In Case No. 6, the telephone line was over-built by the power company after the telephone line was in service ten years. The power company's feeders operated at 600 volts. In some places the feeder was in contact with the cross-arms of the telephone company. The telephone company complained of noise on the telephone circuits. The noise increased to a serious extent when the voltage was raised from 600 to 1200 volts. The section affected covered 12 miles. The telephone company tried transposing its wires but with no effect. The cause of the trouble was a 1250 cycle alternating current generated on the 1200 volt direct motor generator, due to armature teeth on the direct current end. This was remedied by resonant shunts placed across the direct current terminals of the generator.

In case No. 7, the transmission line voltage was 140,000 volts. The power line paralleled a telegraph line. The telephone company complained of induction and chattering of relays, making it difficult to use instruments, also fires caused in the railroad station. The distance between the centers of lines was 21 feet. The remedy applied was the moving of the telephone lines at the joint expense of the power company and the telephone company.

In Case No. 8 mercury arc rectifiers were used for running a trolley road which paralleled the telephone line for seven miles—5,000 volt mercury arc rectifiers; 5,000 volt trolley line. The telephone company complained of disturbance on its toll lines, and to remedy this resonant shunts designed for arc rectifiers were applied, taking off most of the disturbing influence.

F. D. Nims, Seattle, Wash.: I know of a case of inductive interference which was set up at 30 miles, but the line operated

at 55 kv-a. We found peculiar noises at times in our transmission telephone, and it took us some time before we finally realized the fact that they were due to the charging of electrical arresters. We established that definitely. They were very distinct and very plain. The noise was not enough to be at all obnoxious, but the question comes up, if we can get those conditions and actually hear the charging of lightning arresters 30 miles away, what are the telephone companies going to say as to a parallel when you have a distance of 30 feet, or is it a question of a mile or a mile and a half or what is the distance that constitutes a parallel?

MR. MORROW: Speaking of the charging of lightning arresters, we have a time fixed for charging our arresters, and at that time try to avoid the use of the private telephone. We have had cases of 15- and 20-mile parallels where there was danger of rupturing the ear drum of the telephone operator when the arresters were charged. We fix a time, and at that particular time everybody gets away from the private telephone lines.

MR. SPROULE: Is there anything further on the question of inductive interference?

MR. TAYLOR: I think there was some confusion in the contribution of Mr. Morrow between telephone and telegraph. Apparently it was a telegraph he was speaking about. Apparently he was confused with the figures presented. It was a Western Union telegraph line, wasn't it?

MR. MORROW: Telegraph and telephone both.

MR. TAYLOR: In reading the report it referred to a telephone, and I presumed it was telegraph. What I want to say is this, when you have a network of wires, as you have almost everywhere in the country, it is possible to get a disturbance by what you might call a secondary induction, and this case noted of a line 30 miles away might be explained readily on the assumption that the disturbances on the line where the arresters were being charged were indicated by some roundabout processes which I won't take time to outline. I don't mean it is not possible to have a disturbance at any distance. It is just a ques-

tion of sensibility of apparatus. But there are peculiar cases of a power line paralleling a telegraph, where the charge will not be developed itself, but the disturbance might be transferred to some other line, which might in turn parallel the telephone line in some places where the disturbance is found. In other words, you can have disturbance on your telegraph and telephone lines, and the circuits can follow over these two wires in such a way that they do not have to flow through the apparatus, and that disturbance might by the secondary induction disturb something else. In regard to the question as to what constitutes a paralleling, the fault seems to be that there has been set up no criterion of disturbance nor a criterion of paralleling. It seems to be entirely in the hands of the telephone company to raise its hands and say it is bothered.

Mr. Sproule: The next question is overhead line regulations, recent commission regulations and application of the National Electrical Safety Code. I think we can defer discussion on the latter subject until after the discussion of the report proper. The question following is that of the joint use of poles by power and telephone circuits.

C. S. Van Dyke, Schenectady, N. Y.: On the joint use of poles and the limitations of voltage, we have run into this condition:

In some of our rear lot lines we have 2300 volt lines on concrete poles. The Telephone Company has objected to going on these same poles with telephone circuits. The construction is to place the 2300 volt circuit on a wooden crossarm with standard insulators. This has been in use for a couple of years. It has not been definitely agreed whether or not these poles will be jointly used.

Mr. Morrison: As to the matter of stepping poles used jointly by electric light and telephone companies, there was a recent decision rendered where a boy was injured by climbing a pole, and the company was held liable for allowing the steps to be so convenient for climbing. The telephone company has been erecting poles that we occupy jointly and has been stepping them within a foot or two of the ground, whereas on our poles we do

not step within nine feet. We have tried to make it not so convenient.

Mr. Turner: Before Mr. Spencer answers that question I would like to ask also if he noticed any tendency on the part of the telephone company to reservations in their joint agreement. We have recently noticed that tendency on the part of the telephone companies.

Paul Spencer, Philadelphia: Replying to Mr. Morrison, I have not the specifications before me. It is my recollection that the matter of steps is taken care of and that steps are stopped seven feet from the ground. Is that right, Mr. Silver?

Mr. Silver: I am not sure, but it agrees with the Bureau of Standards' specification.

Mr. Spencer: In other words, the steps are not brought to the ground. In regard to the question of reservation of particular lines, that is in the contract as applying to both companies. Both companies have a right under the contract to object to the use of any particular line for joint use.

O. B. Reemelin, Dayton, Ohio: Regarding the question brought up about the joint use of poles, a contract was presented to the Dayton Power & Light Company, and we found before the contract was really thoroughly considered that the Telephone Company would not consider 6600 construction with its main pole lead but would consider 6600 volts on residential lines. In fact, on all residential leads that were convenient to the telephone company, it would get on the Dayton Power & Light Company's poles, under 6600-volt construction and if asked for an agreement would never enter into one.

Mr. Spencer: There is just one point brought up by the last speaker, and that is with regard to just how much existing joint use there is; with circuits in excess of 5,000 volts. The telephone companies say they will not enter into a joint use with 5,000 volts, but undoubtedly they are doing so in many places. The Committee would be glad to know of specific instances where the telephone companies are now using poles jointly with circuits which are in excess of 5,000 volts.

Mr. Silver: I do not feel that I can add anything to what has already been said, but I will offer a word of explanation concerning the intended standardization of line materials. The Committee did not get down to active work on this item this year, but has endeavored to get the matter shaped up so that it can be passed along as a part of next year's activities if the Committee then desires to take it up. In closing, I merely want to emphasize that the Committee is anxious to serve in any way that it can, to help the different companies, scattered all over the country and operating under different conditions, to coordinate their efforts in developing such matters as inductive interference, joint use of poles and others pertaining to its field of work.

J. A. Brundige, New York City: I want to suggest a few things on the line of insulator investigation:

The report of the Committee on Overhead Lines and Inductive Interference touches upon insulator deterioration and suggests the need for a comprehensive insulator analysis and research of the subject, particularly in the matter of design and manufacture. The subject of insulator deterioration is undoubtedly one of serious importance to operating companies, for notwithstanding the efforts which have been devoted by manufacturers and other investigators towards producing insulators which will give good service over an extended period, little progress has been actually demonstrated. For example, the more recently manufactured suspension insulators of the cap and pin type, that is those produced during the last four or five years, appear to give trouble to approximately the same degree as those manufactured in earlier years. This is borne out by reports received from a number of sources indicating that the rate of failure of vertically hanging units as usually determined by meggering, amounts to roughly 4 per cent per annum, while those mounted in the tension position fail at a rate sometimes exceeding 10 per cent. It is well understood, however, that this deterioration ordinarily does not begin to manifest itself until after approximately three years in service, or more properly speaking, three years from date of manufacture, assuming that the insulators have been exposed to weather con-

ditions during such time. In certain cases, however, the trouble has not begun until the fifth year.

There is some question, however, as to whether such high rate of deterioration continues indefinitely. Insulators on certain of the older lines tend to show a slight falling off in the number of failures, and it would be interesting to establish whether there are certain individual units which will last indefinitely. Assuming this to be the case, and that these units could in some manner be located immediately, a critical study of their makeup should disclose the reasons for their superiority over the apparently similar units which continue to fail.

Pin insulators are also subject to deterioration in a somewhat similar manner, but this fact has not been generally recognized until quite recently, which accounts for the rather meagre data in this direction. Trouble, so far as observed, seems to predominate in the larger sizes, but the nature of the real cause is as uncertain as with the suspension type. Certain insulators of early design have been observed to give good service for a considerable period of years and then to begin to fail at an alarming rate. Other lots of pin type insulators designed upon more recent lines and presumed to be quite free from dangerous expansion stresses, have failed within two or three years from the date of manufacture. In practically all cases the failure manifests itself by one or more cracks in the upper shell in the vicinity of the side groove, starting in a circumferential direction and often continuing so as ultimately to bend out radially toward the edge of the skirt. From the direction taken by the cracks, there can be little doubt that the trouble arises in some manner through expansion, but whether caused by the presence of cement or by some internal action in the porcelain, is not certain. It has been felt by some investigators that the amount of cement used in assembling should be kept at a minimum, although instances pointing to the reverse have been brought to the attention of the writer. These features are mentioned to show some of the difficulties yet to be solved.

As a mode of procedure in attacking this problem, the writer has in mind the collection of very complete data on the performance of all types and makes of insulators in service over a period of years, taking into account climatic and other condi-

tions, and from such data to tabulate suitably or draw performance curves for each type. These data might then be turned over to the manufacturers to aid them in a critical study of the internal characteristics of the insulators in question, the results of which should point the way to improvements. The only source of information on performance is the power companies, and in view of the probable relief from the present cost and difficulties of patrol testing, it is felt that the companies would readily respond to a request from the proper source to adopt a uniform record for the tabulation and forwarding of test results.

In adopting a standardized data sheet form, upon which to record insulator performance, it is suggested that spaces be provided for keeping all incidental data such as whether the insulator supports, if on wood poles, are grounded and whether an overhead ground wire is employed. The method employed in testing should be stated as well as the frequency of carrying out such tests. Should the rate of deterioration vary materially on different sections of lines, such information would be of prime importance, especially when accompanied by a statement of conditions, such as variations in altitude of line or changes in climatic conditions, or whether the mechanical forces acting upon the insulators are different.

As a means of determining the age of insulators, it is recommended that the manufacturers adopt a system of stamping the porcelain parts with the date of fabrication. Otherwise no certain means exist of identifying the age of any individual unit, because replacements are more or less continually being made.

It is felt by the speaker that the insulator problem is by no means solved and that the most immediate results can be secured through cooperation by the power companies in placing coordinated and well analyzed performance data in the hands of the manufacturers. The Committee on Overhead Lines and Inductive Interference would seem to be the logical body to initiate the collection of data, and it is recommended that it consider the subject with the view of taking early action.

Mr. Sproule: There is a special notation in the program to the effect that following this report there is to be a special dis-

cussion of the report of the Committee on Safety Rules and Accident Prevention relating to the revision of Part II of the Rules for the Installation and Maintenance of Electrical Supply and Signal Lines of the National Electrical Safety Code. The revision of this section of the code has been under way by the Bureau of Standards for about a year and there are a number of questions pending of importance to the industry regarding which, it is felt, a free discussion should be obtained.

I will ask Mr. Eglin to open this discussion.

W. C. L. EGLIN, Philadelphia: Mr. Chairman and gentlemen, I had this announcement put into the program because of the short time available in which to discuss the report when it is formally presented on Thursday. There has been so much discussion in various sections of the country regarding the Safety Code, and there have been so many misunderstandings regarding the attitude of the Bureau of Standards towards the Safety Code that I thought it well to make some explanation, and then on Thursday afternoon we hope to hold a special meeting in this room, at which we can get right down to a working program for the balance of the year, based on the wishes of the members of the Association, their relations with the Bureau of Standards, and on such revisions as they desire to make in Part II of the Safety Code.

At the beginning of the war, Mr. Lieb, then President of the N.E.L.A., and myself as Chairman of this Committee, and Mr. Carty, as Chief Engineer of the Telephone Company, visited the Bureau of Standards and stated that on account of war conditions none of our companies, or the telephone companies, had any time to devote to the further preparation of rules or revisions of rules, and that the code as then issued should be continued until the close of the war on the basis of a trial use and trial use only, and until we could get some of the results of the application of the code before us, in order to determine whether the code was to be revised upwards or downwards So far that has been true. The Bureau has kept faith and the companies have gone right along and but few companies have really adopted the code, although some have tried on their new construction to follow out carefully the code's rulings. Now, we have reached a condition today where the present edition of the Code is ex-

hausted, and a new one must be printed. Naturally the Bureau does not want to reprint the old edition because errors exist in that edition. It wants to change these, and to change the language of some of the rules. Your Committee has been in close touch with the Bureau throughout this revision. There are some further revisions and some basic changes that the Bureau wants made in the code, and our Committee has naturally taken the position that it is not prepared to make any changes in the code until there are some more definite expressions of opinion from the Association. As has been pointed out, there are many difficulties in an Association of this kind in developing a code on account of the many local differences and standards of practice of different companies. So it becomes necessary to work out here, if we can, some plan by which we can really cooperate with the Bureau of Standards, and I would like to remark right here and now that I hope no one has come here with a notion to do anything to defeat or interrupt or hold back the progress of these rules. What we have to do is to try to work out a workable safety code—not an unduly hard code—and not to try to interrupt or interfere or delay. I think the Bureau has shown a tremendous amount of patience—that is, the personnel of the Bureau—in its dealings with us. I am sorry to say that our attitude in the past has been more or less of a holdback one and we have not attempted to get the code into use as rapidly perhaps as we could. If we have any feelings of that kind, the sooner we leave them outside the room the better. We must get right down to business in these meetings, and we want at the meeting Thursday afternoon in this room to hear everybody who is interested. We want suggestions as to how we can practically cooperate in the best possible way with the Bureau of Standards in order to get a code that is a workable code, one that will not produce undue hardship but will produce safe construction; I, for one, feel that we must have safe construction, and that anything the Bureau can show us is not safe we must be ready to modify; I hope that on Thursday afternoon we shall have a good attendance, representing the various sections of the country, and I hope that all the California members will be present because it is very important that our Committee should have the help of these men.

Before sitting down I want to acknowledge that I have done none of the work as Chairman of that Committee and to express my thanks to the engineers representing some of the larger companies in their distribution systems, who have even during the war given a good deal of their time to the studying of parts of the code and in helping to maintain good cordial relations with the personnel of the Bureau of Standards; I am glad to say that I believe the Bureau of Standards has every confidence in your committee. Thank you.

Mr. Sproule: Supplementing what Mr. Eglin has said, I might add that the present code is out of print. Before printing additional codes there are certain revisions which have been suggested to which your Committee has taken exception; the main question being that of loading. They have increased the loading to a limited extent in its application to Class B and Class C lines. I would be glad to hear from any one in the room who has anything to put before the Committee.

Augustus T. Throop, Utica, N. Y.: May I ask how you can modify the scope of a committee on underground construction so that it would include submarine construction.

Mr. Sproule: I would suggest that you refer that question to the Secretary of the Hydro-Electric and Technical Section. Is there anything further in reference to Section 2 of the Safety Code?

C. F. Scott, New Haven: The thing that has impressed me in the several discussions this afternoon is the attitude, referred to particularly by Mr. Eglin, with which the Association is going at its work. It is one of constructive, cooperative effort. I remember a matter of inductive interference in a case that came up a number of years ago, in which a telegraph company suffered severe interference at times from a power company. The power company, however, refused to make known the conditions of its circuits on those particular days or hours when the trouble occurred. That left the matter in a very unsatisfactory condition, as the telegraph company did not know the specific cause of the disturbance. Matters in which the different interests are inter-related, with telegraph and telephone companies

and the power company on the one hand, and matters of safety in which the power companies and the public also are interested, are primarily engineering problems. They are not legal matters; they are not commercial matters primarily, but engineering; and they ought to be handled from the engineering point of view. The matter of interference, for instance, is a very difficult and intricate one, because so very many conditions are involved, and they are not the same in different cases. Almost every case has its own special features which cannot be dealt with along purely general lines. I was in a conference a number of years ago in which some problems of interference were taken up, and at which the then president of the American Telephone and Telegraph Company was present. He said that difficulties would first be put up to the engineers of his company and he hoped that all the other companies involved would treat them as purely engineering problems. His engineers were not to be restricted at all by the possible legal or business outcome. He hoped that the difficulties could be solved in that way, but if not, then recourse could be had to other means. The whole attitude of the Association this afternoon in the matter of interference is along these definite constructive lines in settling things as they ought to be without undue prejudice and stubbornness and selfishness on the part of one company or another. In fact all these electric concerns are public service companies and it is their business to adjust themselves so that they may together render the best service.

Mr. Sproule: If there is no further discussion on this subject, a motion to adjourn will be in order.

On motion the meeting adjourned.

THIRD TECHNICAL SESSION

Wednesday. May 21, 1919

R. J. McClelland, Chairman.

The Chairman called the meeting to order at 2 p.m.

The Chairman: This is the Third Technical Session. There are two parts to this meeting this afternoon, the first is to consider the report of the Committee on Electrical Apparatus, and the second is to consider the Report of the Committee on Meters. We will take up the Report of the Committee on Electrical Apparatus, of which Committee Mr. R. F. Schuchardt is Chairman. As Mr. Schuchardt is unable to be here, Mr. A. H. Lawton, of the Committee, has kindly consented to present the report and act as chairman.

REPORT OF COMMITTEE ON ELECTRICAL APPARATUS

INTRODUCTION AND OUTLINE

The purpose of the Electrical Apparatus Committee is to study the performance of electrical apparatus used in connection with a central station system and to cooperate with the manufacturers so that its development will be along lines which will serve the industry most satisfactorily. The Committee also aims to present experience results to the members showing how best to protect the investment made in the electric plant and how to obtain the most satisfactory return from it.

The stimulus given to apparatus development by previous annual reports of the Apparatus Committee suggested the advisability of having the Committee serve the membership in this wise more often than once a year. It is therefore recommended that this Committee, through its sub-committees (to be referred to later) serve constantly as a clearing house for experience data, at least with reference to the major apparatus used. Member companies are urged, when corresponding with the manufacturers regarding the faulty (or the correct) operation of any apparatus, to send to the sub-committee chairman whose field includes this particular apparatus, a copy of such portions of the correspondence as set forth a clear statement of the experience. The manufacturers in turn will be urged to place on record their explanations or plans for improvement. In this way it is hoped to collect and have ready for reference information covering experience with oil switches, generators, fire-fighting devices and other protective equipment, etc., etc. The sub-committee chairman receiving information from a member company will, in acknowledging receipt, inform the member of any similar experiences reported by other companies, and he will also state the method used to correct or improve, if such information be available. For some particular apparatus which is undergoing development, as for instance large capacity oil switches, it is planned, with the aid of the manufacturers' engineers, to prepare forms to be filled in by member companies to show the important attendant conditions and the nature of failures (or, in some cases, of successful performance). How this clearing house scheme, when it is fully in operation, can speed up the desirable development of appa-

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Manuscript of this report was received April tenth.

ratus, will readily be appreciated. Its success, however, will be in direct proportion to its use by the member companies. For the present, the sub-committee chairmen will be those given in this report. The appointees for the succeeding committee and any subsequent changes will be announced in the monthly BULLETIN.

Due to the lateness of the appointment and subsequent organization of the Committee this year, the Sub-Committee for the Pacific Coast was unable to contribute to the work as completely as it would otherwise have done. This fact, however, resulted in the suggestion from the far western members that in the future the members of the Engineering Committee of the Pacific Coast Section of the N.E.L.A. be made the appointees from the Coast on the Electrical Apparatus Committee. This suggestion is worthy of serious consideration.

For the purpose of covering the important items more expeditiously and more completely, the field of the Committee was divided into six main subjects, each of which was assigned to a separate sub-committee. These subjects, with a general summary of the sub-committees' reports, follow. The detailed reports will be found on the succeeding pages.

GENERATORS

The rapid increase in the use of very large generator units brings with it the necessity for satisfactory means of protecting them from the effects of external trouble and for provisions to minimize the effects of internal trouble. The failure of such a unit means not only large expense for repairs, but even the temporary loss of its use results in higher operating costs, because the older and less efficient units will have to carry the load otherwise carried by the large unit. Because of this fact, increased attention is now being given to relay protection of a nature to disconnect promptly a unit which has failed, and also to fire-extinguishing equipment which will minimize the damage from a generator breakdown, if this results in burning, so that the unit may be repaired more quickly and cheaply. The Sub-Committee's report sets forth the experience to date with the protective measures here mentioned. Various incidental features of the problem are included.

SWITCHBOARDS

(*Particularly oil and air circuit breakers*)

Active steps have been taken during the last few years to put the matter of capacity rating of switches on a more logical and uniform basis. Considerable work along this line has already been done, particularly by the A.I.E.E. and by the Power Club. There still remains, however, considerable lack of uniformity and even of clear understanding regarding the ratings, especially of the large size switches. For the purpose of clearing up some of the apparent inconsistencies and of obtaining more definite data regarding switch capabilities, the Sub-Committee suggests to the manufacturers a definite plan of research and sets forth the data which it believes should be obtained in order that the users of these switches may have the necessary information regarding them.

The Sub-Committee also calls attention to the point already mentioned in previous reports, that air break switches should be rated very liberally with regard to current-carrying capacity, because of their rapid deterioration, resulting from high temperatures.

A new development in an automatically operated air break on oil circuit breakers is described, and a further development in a safer design of current transformer is mentioned.

TRANSFORMERS

A continuation of the very important work of standardizing transformers, begun in 1916 and improved during the following years, has been the main work of the Transformer Sub-Committee. The booklet accompanying this report for 1919 brings down to date and sets forth in convenient and logical form the results of this work. Its careful study on the part of the engineers of the member companies will be found profitable.

SUBSTATIONS

There is at present great variation in the practice of various companies with relation to substation installations. While in most cases there are good reasons for such variations, it is thought that a comparison of practice could be made with profit. This is particularly true in regard to those simple transformer installations made on the premises of customers using a large

amount of power. For the purpose of obtaining data for such a comparison, the Sub-Committee sent a questionnaire to a large number of representative companies, and the information received as a result is set forth in the attached report. Considerable data are given with regard to the practices of various companies, together with a discussion of the apparatus used. The report covers all classes of substations, both indoor and outdoor, for direct current supply and for alternating current supply for light and power and for railway use, automatic, semi-automatic and manually operated.

POWER FACTOR CORRECTION

The importance, emphasized particularly during the war, of utilizing existing investment to the highest degree has again brought prominently to the fore the increased carrying capacity of lines and equipment and the better regulation that results from improvement in the power factor of the load on our systems. The Sub-Committee presents a valuable summary of the situation and suggests that since improvement in power factor frequently results in sufficient advantage to justify its cost, more serious consideration be given to this subject than it has received in the past. A general discussion of apparatus available for power factor correction is included, together with a comprehensive bibliography on the subject.

APPARATUS FOR SPECIAL INDUSTRIAL FIELDS

This Sub-Committee has compiled a very interesting summary of apparatus required in the following applications of electricity: welding, both resistance and arc types; furnaces for all purposes, including steel, brass, ferro-manganese, etc., etc.; and the various uses in mining and in oil fields.

Some of the difficulties experienced with this apparatus and some general comments to aid power companies in handling this class of business more satisfactorily are included. The report gives a fair idea of the possibilities for business that may be found in these fields.

There is one thought which the general situation in the industrial field suggests; namely, the desirability of closer contact between the engineers of various industries and central station engineers. This could be brought about in a measure by

closer cooperation between the organized engineering societies. Such cooperation should aim to prevent development along divergent lines, as for instance, with relation to frequency. It is generally recognized that the future frequency, at least for all new developments, will be 60 cycles, while the steel industry in some localities is still apparently developing along 25-cycle lines. All development should be guided by a consideration of the trend of the entire industry so that no avoidable investments will be made, which will later have but limited value because they do not properly fit into the general scheme of things. The handwriting on the wall points clearly to comprehensive interconnection, and engineers should keep this in mind in all of their plans.

REPORT OF SUB-COMMITTEE ON GENERATORS

Considerable attention has lately and is now being given by member companies to the matter of fires originating within the generator shell of turbo-generators of the enclosed type with the object of—

(a) Determining means of minimizing the occurrence of such fires.

(b) Limiting the extent of the damage to as small a section of the generator as possible.

(c) Providing fire-fighting equipment which can be applied quickly where it will be most effective.

The heavy loads carried by generators during the past two years and the inability to take the units off of the line for proper cleaning and inspection at the accustomed intervals, brought about by the heavy demands for power resulting from war conditions, have increased the number of generator failures and fires and thus emphasized their seriousness, not only in cost of repairs but even more in the enforced idleness of the entire unit during time of repairs. The desirability and necessity for more careful study of this entire question are therefore evident.

In response to a questionnaire sent early in March to sixty-four member companies operating generators of comparatively large size, replies were received from thirty. The information received, recording experience of member companies along the lines indicated, has been tabulated, compared and carefully studied and summed up as follows:

HISTORY AND EXPERIENCES WITH FIRES

Number of Fires

The total number of fires referred to by the thirty companies returning questionnaire was eighty-one, their occurrence being within the past three or four years. Twenty-one fires, about equally divided between 25 and 60 cycle units, were specifically described, occurring in units ranging from 3300 to 35,000 kw. and 2300 to 13,200 volts.

Origin and Cause

The origin of the fires reported seems to be fairly evenly divided between those external to the insulation surrounding

the copper conductors and those internal from the conductors themselves. In many cases all evidence on this point is destroyed by the fire itself. The greater proportion of fires originating from sources external to the insulation seem to have occurred on 3-phase systems operating without a grounded neutral.

The various fires have been attributed to many causes—about one-third of the number reported appear to be due to short circuits between conductors, and a greater number to grounds, while the remainder are divided among mechanical causes, eddy currents, corona and moisture from faulty operation or from freezing of air washing apparatus, condensation, etc.

Nature and Extent of Damage

Most fires have been reported as smoke or flame producing, the smoke from by far the greater number being stated as heavy and voluminous.

In most fires the damage has been localized initially in individual coils or groups of coils, but twenty-two of the thirty companies reporting have had cases where the trouble has spread so as to involve the entire winding, which was seriously damaged. In quite a number of instances sections of armature laminations have been burnt sufficiently to necessitate replacement.

FIRE PREVENTION

Cleaning and Inspection—Air Supply

The inspection and cleaning of turbo-generators at more frequent intervals would seem to be very desirable and to have a direct bearing on the liability to fires from sources external to the winding. Every precaution should be taken to limit the amount of dirt and oil which may enter the generator, and many companies, particularly on the larger units, have standardized the installation of air washers. Even with the best possible condition of cooling air, however, it is evident that dirt will lodge within the generator, and if a certain amount of oil vapor is also carried into the machine, the coil surfaces and other parts may become coated with grease. Good practice, therefore, would seem to indicate that machines should be opened up periodically for thorough cleaning and possibly for painting. There seems to be a wide difference in the practice of member companies with regard to the frequency at which such inspections and cleanings

are made. It would pay to give attention to the matter of cleaning at least once a year.

Additional Insulation on Armature Coils

One member company feels that additional insulation on the armature coils of generators is as satisfactory a method of reducing the fire hazard as any that has so far been suggested. It is thought that this has a distinct advantage, and in some units it can be obtained for such a small increase in price that it may be the cheapest of all methods of reducing fire hazard. On two 35,000 kw. units for initial operation at 6600 volts, arranged for future operation at 11,000 volts, the manufacturer has guaranteed a high potential test on individual coils of 40,000 volts and on the complete machine of 34,000 volts.

Grounded Neutral

The grounding of the neutral of 3-phase systems solidly or through resistance is rapidly becoming standard practice on both 25 and 60 cycles throughout the country. Twenty-one of the thirty companies replying favored this method of operation, five preferred operating with solid ground, and sixteen preferred operating through resistance; three companies opposed the grounding of the neutral. The consensus of opinion seems to be that grounding is very desirable and, in addition to other advantages, has a considerable effect on the reduction of generator fires occurring external to the insulation of the copper conductors.

PROTECTIVE EQUIPMENT

Balanced Relay Protection

It is also rapidly becoming standard practice, particularly on larger units, for the manufacturer to bring out both ends of each phase winding to the generator terminal boards, so as to permit the installation of current transformers between the terminals of the phase windings and the neutral of the coils. These current transformers can be connected differentially with respect to instrument current transformers in the leads between main oil switch and generator, so that in the event of a fault in the generator or its leads the balanced relay will immediately open the main oil switch, the neutral switch (if closed), and after a slight delay the field switch. Twenty-four of the thirty companies re-

porting approve the installation of balanced relay protection and have adopted it as standard practice on all new generator installations and on older generators where the expense involved is not too great. The field switch is usually opened by means of an auxiliary switch on the main oil switch or by an auxiliary relay, so that there will be no chance of the field being opened before the armature has been disconnected from the system.

In the past there has been great reluctance to install any automatic features on generator equipment because of the fear of their erroneous operation. In 1912 a member company installed balanced relay protection on tie line cables between two nearby generating stations, and their operation was so successful as to lead to a willingness for trial installation of balanced relays on a generator being installed in 1914. From that time on this equipment has proved very satisfactory and has been extended to all new machines on that system. It has now been rapidly adopted by other operating companies. The best evidence of the value of this protection is furnished in the reports of generator failures on which this protection was employed.

On a 25,000 kw. unit there have been three armature coil failures in the past three years, on all of which occasions the balanced relay operated, and on two occasions the damage was confined to the coil where the breakdown occurred. A slight amount of damage occurred to the laminations in one of these instances, not sufficiently severe, however, to necessitate restacking. At the time of the third failure mentioned, the field switch failed to open, owing to defective operation, and the iron in the coils of the upper half and the insulation on the end connections at one end of the lower half were badly damaged. It was necessary to restack the iron and to rewind the upper half of the armature and to re-insulate the field completely. There is every reason to believe that, had the field switch opened properly, the damage would have been confined to the coil where the break-down occurred, thus very greatly reducing the cost of repairs.

Another member company installed balanced relay protection on the leads of four 15,000 kv-a. generators in 1913, and after some cases of successful operation of such relays on generator cable trouble, it decided in 1916 to extend the protection to the generator windings as well on all new units. Several in-

stances of successful operation during trouble on both generator windings and leads have occurred since, testifying to the value and reliability of this protection.

Reverse Power Protection

Before the introduction of balanced relay protection for generators, many companies installed reverse power relays, arranged, however, to operate signal lamps for indication to operator instead of tripping main oil switch. This was due to the fear of erroneous relay operation, which had actually occurred at times of system disturbances when generators were somewhat out of step. The reverse power relay thus does not limit automatic disconnection from the line to failure of the generator itself. The installation of reverse power relays is somewhat complicated in comparison with the very simple connections for balanced relay protection.

FIRE FIGHTING

General

The modern type of turbo-generator is usually completely enclosed and subject to enormous blower action for proper ventilation, so that fires in them become quite serious and very difficult to extinguish. It should be particularly borne in mind, however, that the time element is the main factor in putting out any fire, and it is especially important in electrical generator fires to apply the extinguishing medium as promptly as possible and as close to the seat of trouble as can be done without danger of permanent injury.

Extinguishing Methods

In the methods thus far adopted for extinguishing electrical fires, water, steam and carbon-tetra-chloride have been used. Water and steam are looked on at present with favor. Large volumes of carbon-tetra-chloride would be required for any but very small fires, thus involving great expense, with the added possibility of detrimental effect on the insulating materials and injury to operators from contact with the fumes. Moreover, it is quite difficult to apply this substance to the flame itself, and its use is therefore relatively ineffective.

Up to the time of the installation of permanent fire extinguishing apparatus for generators, water, because of its greater

availability over steam, has been the principal medium for extinguishing, where Pyrene was ineffective. Experience has demonstrated, however, that it is extremely difficult to put out a fire in the generator before extensive damage has occurred without applying water directly at the seat of the trouble. In many cases reported it has been necessary to remove the end bells and direct the water stream on the windings.

With the advent, however, of permanently installed fire extinguishing provisions in generators, the use of steam has received very serious consideration, and there is at the present time a wide difference in opinion as to the relative merits of water and steam for this purpose. Of the thirty companies reporting, the use of water is definitely favored by nine and opposed by eight, and the use of steam favored by seven and opposed by twelve. Eighteen generators of four companies are now provided with permanent steam equipment, as against nine units of three companies with water equipment.

The principle of operating in using steam differs from that in using water primarily in that displacement of air in the generator by steam is very largely depended upon to smother the fire. It is extremely important, however, in using steam to shut off the supply of air to the generator as completely and promptly as possible, and some means of facilitating this operation should be provided. It would seem that the air damper could be placed more effectively in the outlet rather than the inlet wherever the design permitted. The wetting of the generator windings from condensed steam may also be helpful. In using water, the idea is to wet the windings as far as possible, this being aided by the natural ventilation of the machine.

The possibilities of liquid carbon-dioxide or other noncombustible gases or liquids have also been discussed, but no advocates of these materials have been found.

Character of Apparatus

For the ready application of water to the generator windings, the usual practice is to provide pipe rings, which are fastened at each end of the generator inside of the end bells. Perforations are located in these pipes so as to throw a fine spray of water over the entire winding and over the air gap between

the armature and field. The pipe rings are then connected together into a reliable source of water supply under the desired pressure. Fig. 1 shows the general arrangement of this type of installation. The natural ventilation of the machine helps to spread the water over the entire winding.

For the ready application of steam to the generator windings two methods have been used—

1. Steam pipe arranged inside the end bells, perforated so that numerous jets will impinge directly on the end portion of the windings and into the air gap in practically the same way water is used.

2. Location of perforated steam pipe in the air inlet of the generator.

In both of these cases the steam supply is obtained from the branch system mains supplying the auxiliaries of the unit protected. The second plan has been adopted by some companies because of a fear that the steam may have a deteriorating effect on the insulation when it impinges directly on the end turns as in the first plan. Fig. 2 illustrates this type of installation. In applying steam it is the rule of one company that the valve be

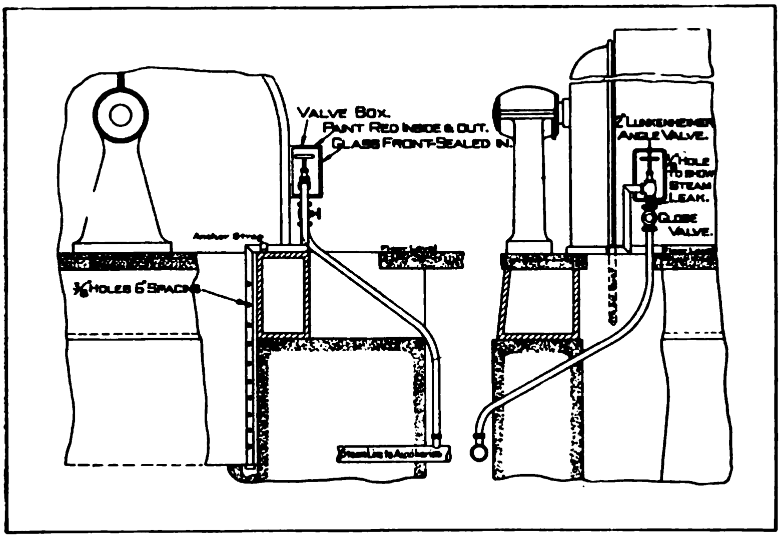
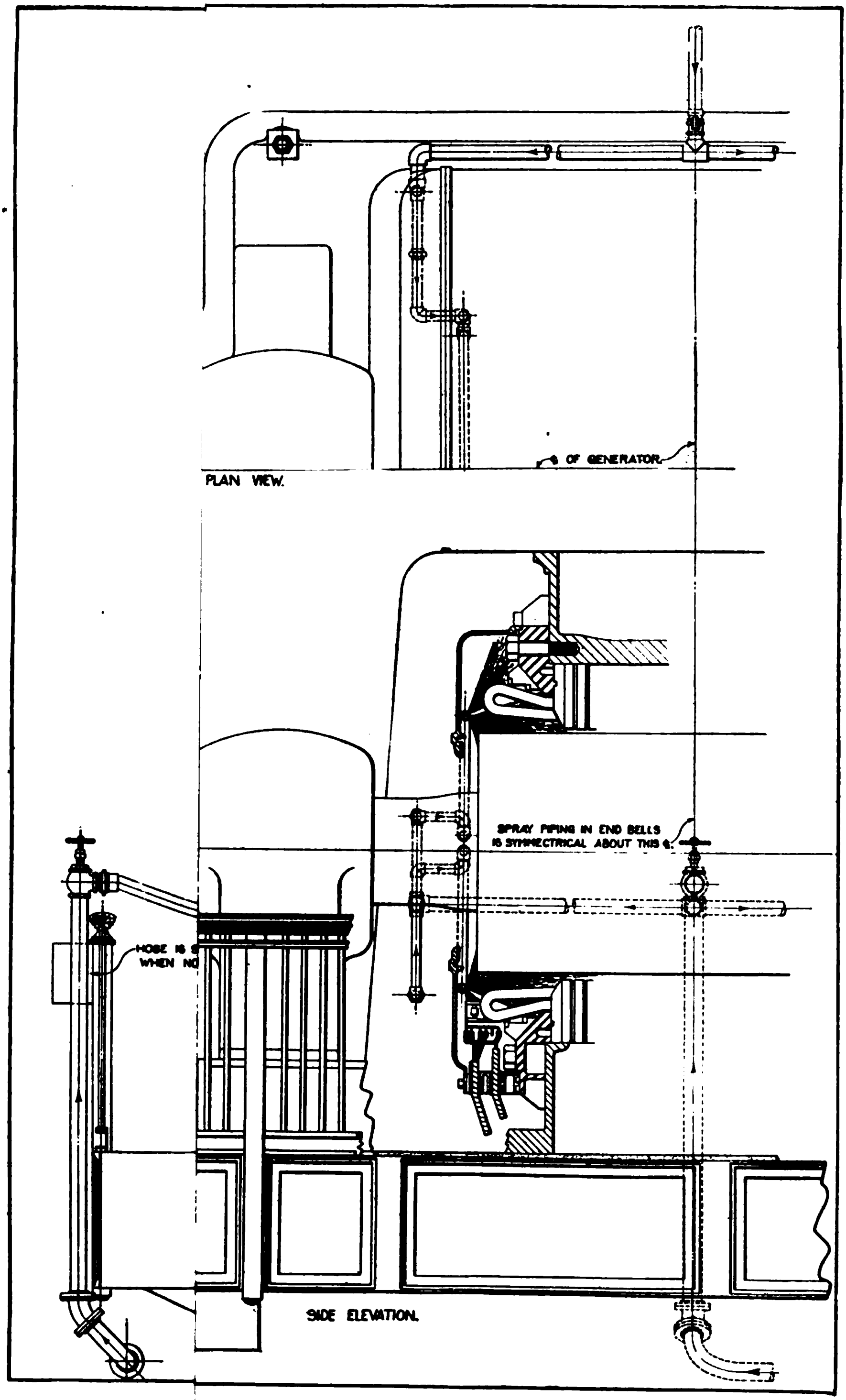


Fig. 2



℄ OF GENERATOR
PLAN VIEW.
SPRAY PIPING IN END BELLS
IS SYMMECTRICAL ABOUT THIS ℄.
HOSE IS S
WHEN NO
SIDE ELEVATION.

opened for two-minute intervals, additional applications being given only if the fire continues.

Safety Precautions

It is, of course, very necessary that the possibility of the application of either water or steam to the generator winding,

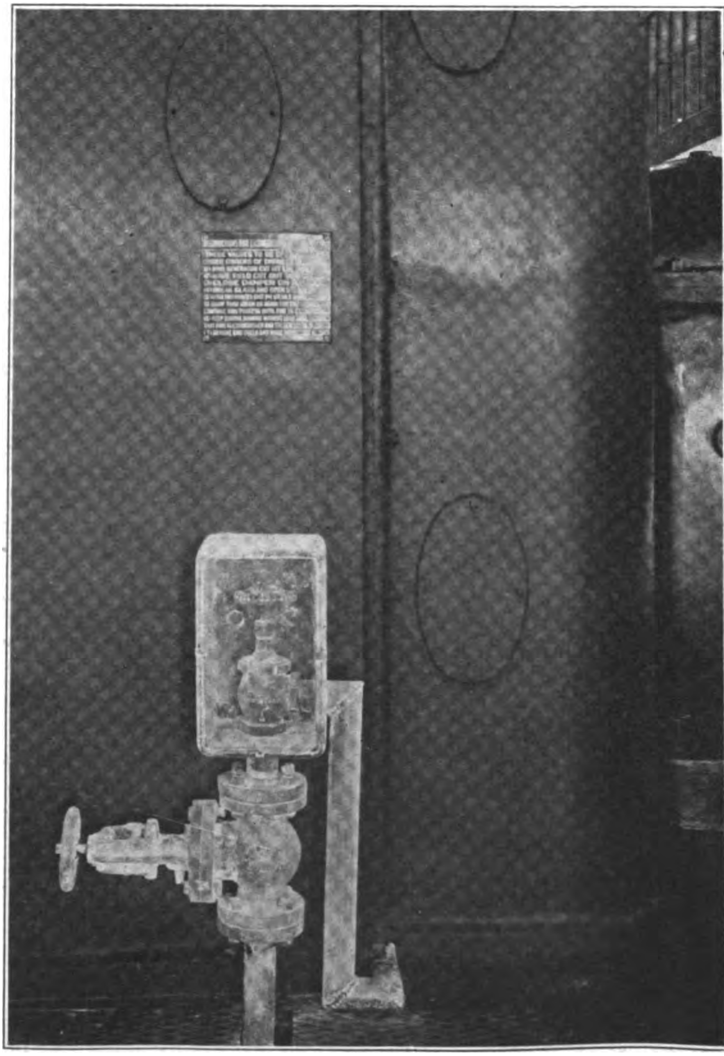


Fig. 3

either accidentally, through leakage or malicious intent, be very carefully guarded against. Various means have been devised to accomplish this purpose. The Duquesne Light Company, in connection with its provision for application of steam to the air inlet under the generator, has arranged the supply pipe to the generator with two valves in series joined by a short nipple, the valve nearer the machine being enclosed in a cast-iron box with glass front, which must be broken in case of a fire before valve can be operated. A small hole is drilled in the pipe nipple connecting the two valves, which will positively indicate any leakage taking place through the first valve. Fig. 3 is a photograph of one of this Company's installations.

The Philadelphia Electric Company, which has provided for the use of water, has arranged that the water supply line is not permanently connected to the generator piping. The free ends of both pipes are provided with Jones or quickly attachable couplings, and a short piece of standard fire hose equipped with

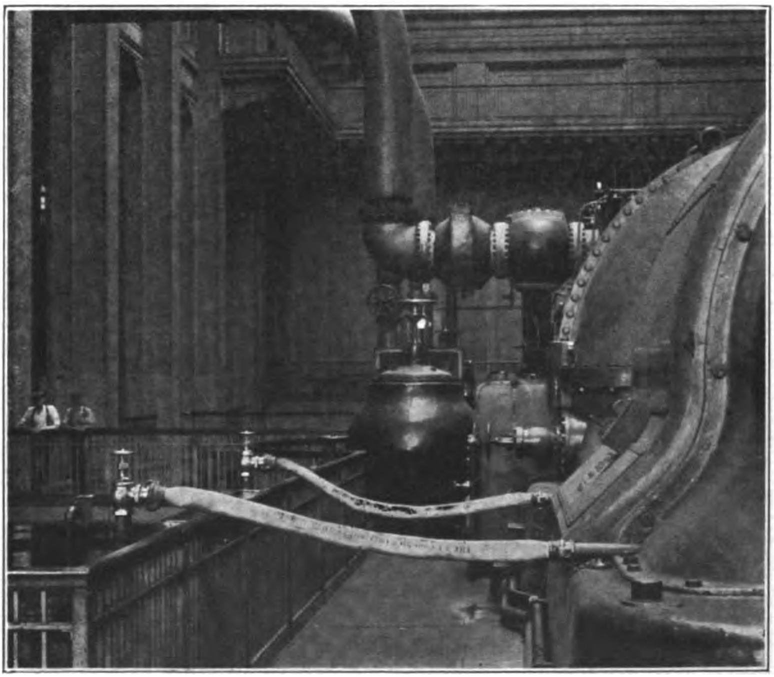


Fig. 4

corresponding couplings is available for making this connection on the occurrence of a fire. Fig. 4 is a photograph of an installation of this type.

Evidence of Fire and Application of Extinguisher

With generators discharging air at the top into the turbine room, indication of fires within is promptly given to attendants by sparks, smoke or flame emerging from the unit. The tendency lately, however, in generator design, particularly in the larger units, has been towards bottom discharge into ducts leading to the boiler room to eliminate noise and to take advantage of the heat in the air. This design brings up a serious problem with regard to visibility of distress. Manufacturers and operators would do well to give serious attention to this matter.

Some few fires have occurred from mechanical causes alone, such as fan rubbing against end bells, producing red-hot surfaces. These have led to an installation of glass windows in generator end bells by at least one member company for indication of such trouble. The advisability of using similar windows at the side of the base is worthy of consideration.

Before proceeding to fight any generator fire, it is, of course, absolutely essential that the unit be disconnected from the line and the field opened. With the balanced relay protection, this is done automatically when fires involve a break-down from the copper conductors on a grounded system. On other occasions the disconnection of the generator must be performed by hand as soon as it is evident that the unit is in trouble. The decision to apply an extinguishing medium and the time of doing so must now be left to the attendants. It is desirable to have a pilot light on the turbine gauge board connected across a generator potential transformer to indicate when the unit is generating, and also perhaps a red lamp on the gauge board to light upon the operation of the balanced relay. These indications would be of value in determining the time when an extinguishing medium could or should be applied. It is very essential, however, that some visible indication be given of actual distress before applying the extinguishing medium.

Effects on Windings of Extinguishing Substances

It will be necessary after application of water to the gener-

ator windings to dry them out before placing in operation again. Experiences have demonstrated that electrical generators may be sprayed with water for some time with no serious damage resulting, if they are thoroughly dried out before being again placed in commission.

Some companies opposed to the use of steam have expressed fear regarding the possibility of detrimental effects of high temperature on the insulation, particularly where steam is applied for a long period of time or where it impinges directly on the windings. The destruction of the japanning on the core laminations by the high temperature is also feared. The Duquesne Light Company, however, has had several fires since installing perforated steam pipes in the air inlet of its machines and reports satisfactory results. Nearly all of these fires were started external to the winding and were extinguished with one two-minute application of steam. On all but two occasions the generator was restored to service without being dried out, having been out of service only from three to four hours, and in one other instance the drying out was done simply by rotating the machine for about seven hours without short circuiting the windings or exciting the field. One fire, starting from a ground, developed into a short circuit, but on only a few coils was the insulation burned sufficiently to necessitate replacing them. This machine was entirely rewound, however, as it had been through a previous fire and was not in the best of shape. It appears, however, that the equipment installed by this Company has not, as yet, had an opportunity to demonstrate satisfactorily its ability to handle severe fires, and until more experience data with such fires are available no definite conclusions should be drawn.

In one instance, it was reported by a western company that steam used for fighting a fire destroyed the japanning of the laminations and therefore made necessary the entire dismantling of the generator armature. Yet the same company has shown its faith in steam for this purpose by installing this means of fire fighting on five of its largest units.

The Public Service Company of New Jersey recently applied steam unsuccessfully to a very severe fire. No companies using a water system have, as yet, had occasion to try it, so that all arguments in favor thereof are merely opinions or deductions.

CONCLUSIONS

According to the information received, several serious generator fires have occurred in turbine driven units of various sizes, voltages, speeds, frequencies, and manufacture. These fires have originated within the generator shell from a variety of causes and have been in many instances very difficult to extinguish before extensive damage has been done.

In order to lessen the probability of the occurrence of such fires, it is suggested that constant consideration be given to the cleanliness of generators.

In order to minimize the extent of damage from fires, it has been found advisable in many cases to install balanced relay protection on turbo-generators, to automatically disconnect the unit from the line and open the field. This practice seems sound and manufacturers are urged to standardize upon the bringing out of both ends of all phase windings to generator terminal boards on all units of 5000 kw. and larger, and also on smaller sizes where no appreciable increase in the selling price of the unit will result.

The practice of installing some form of permanent fire extinguishing equipment is gaining considerable headway and is being adopted by many companies. The substance to be used should be water or steam, the weight of opinion and practice, to date, being in favor of water, although actual experience with specially provided equipment has been obtained thus far only with the use of steam, and that by the Duquesne Light Company to its entire satisfaction.

Operators who have installed or who shortly will install any regular means of extinguishing fires are urged to keep a careful record of all circumstances of their experience for the benefit of the industry.

Subcommittee

H C Albrecht, *Chairman*,
L L Elden,
H L Fullerton,
A A Meyer,
N Stahl,
W K Vanderpoel.

REPORT OF THE SUB-COMMITTEE ON SWITCH BOARDS

This Sub-Committee has devoted most of its attention to the subject of the interrupting capacity ratings of oil circuit breakers, with the thought that through cooperation with the manufacturers, the A.I.E.E. Standards Committee, and the Power Club, a clearer understanding of the entire subject may be reached, some of the inconsistencies of present ratings eliminated and applications of circuit breakers made more suitable to the conditions under which they may be required to operate.

Interrupting Capacity Ratings of Oil Circuit Breakers

The A.I.E.E. tentative definition of "Interrupting Capacity" reads as follows: See 1918 Standardization Rules, Article No. 753.

"By interrupting (breaking or rupturing) capacity is meant the highest r.m.s. current at normal voltage which the device can interrupt under prescribed conditions, at stated intervals, a specified number of times."*

Your Committee has considered the several factors entering into the foregoing definition, from the standpoint of operating companies such as comprise our membership.

The Committee believes that the "prescribed conditions" should be such as would give the most severe requirement on the circuit breaker under actual operating practice, which is usually that produced by a short circuit near or in a generating station; also, that they should be such as could be reproduced in tests. It is therefore recommended that the "prescribed conditions" be those which can be produced in test, with as little resistance as possible in circuit with the generators, and with no other load apparatus on parallel lines feeding the short circuit through the breaker. There might be some exceptional circumstances under

*See joint paper "Rating & Selection of Oil Circuit Breakers" by Hewlett, Mahoney & Burnham in the A.I.E.E. Proceedings, of February 1918, discussing the interpretation of this rule.

which the conditions prescribed above would not be representative of actual conditions, but it is thought that they would satisfy the requirements of the majority of operating companies and that the exceptions could be given special consideration.

As it is generally believed that the power factor of the circuit which a breaker has to interrupt under short circuit conditions has a considerable influence upon its interrupting capacity, it is recommended that the manufacturers work toward the obtaining of data which will enable them to show for any type of breaker the effect of power factor on its rating.

The manufacturers are basing their ratings at present on no definite prescribed conditions, but on an assumed duty that the circuit breaker will interrupt its rated r.m.s. current twice at a two-minute interval, and then be in condition to be closed and carry its rated current until it is practical to inspect it and make necessary adjustments.

Any such assumed duty should be consistent with usual operating practice, and it is our opinion that the requirements of operating practice would not permit a time interval as long as two minutes to elapse before a circuit breaker were reclosed. The time interval would probably range from something considerably less than two minutes, under ordinary operating conditions, down to a few seconds, when automatic circuit breaker reclosing devices are used, toward the adoption of which there is a growing tendency.

It is also questionable whether twice opening and then being capable of reclosing for non-automatic operation is consistent with usual operating practice. Some operating companies require the closing of breakers more than twice on distribution feeders and the holding off of large generating station breakers after once opening until they can be inspected before reclosing. Much depends upon provisions for spare breakers and feeder equipment, and upon the importance of the load served by the particular breaker, whether it is controlling a feeder cable or a transmission line.

The Committee suggests that the manufacturers work toward establishing curves for each type and size of circuit breaker, showing the interrupting capacity for various numbers of interruptions and for various time intervals, from that incident to

the use of an automatic reclosing device up to a two-minute interval. With such curves there might readily be selected a breaker which would be most suitable for the conditions under consideration.

However, inasmuch as the manufacturing companies at the present time have not the necessary information to make the above curves, and as they are still working toward obtaining ratings on their breakers on the basis of two interruptions at a two-minute interval, it is recommended that this assumed duty be followed for the time being, pending the above information, although, as stated before, this rating is not representative of operating practice.

In order to aid the manufacturers in the preparation of the above curves, it is proposed that the Committee gather data on the practice of operating companies as to the number of times breakers are reclosed after a short circuit and the time intervals which are permitted to elapse before the reclosing.

There is at the present time no clearly defined factor of safety incorporated by the manufacturers in their interrupting capacity ratings. It is our opinion that, in view of the many uncertainties attendant upon the actual duty imposed on a breaker, tests should be made to the ultimate interrupting capacity and a factor of safety then applied in the assigning of the rating. This factor of safety should be of such a value as to give a reasonable degree of protection, as evidenced by the results of tests which the manufacturers are contemplating, from those tests already carried out, and from the results of actual experience in operation.

In view of the difficulties confronting the manufacturers in obtaining a sufficient concentration of power for the testing of the larger breakers, and in view of the value which could be derived from evidence as to the successful or non-successful functioning of breakers under actual short circuits, it is recommended that operating companies make reports of such occurrences of importance to the manufacturer of the breaker, giving him such data as will enable him to determine what service the breaker performed. Such a report would preferably be made on a standard form which the Committee, in conjunction with the manufacturing companies, contemplates devising, and a copy sent

to the then Chairman of the Sub-Committee on Switchboards, who could, from a collection of such data, advise the member reporting if similar troubles or successful results had been experienced with other breakers of the same type. It is hoped that in this way more light may be thrown upon the adequacy of breakers of specified ratings to function properly under conditions realized in practice.

Air Break Switches

Experience is showing that the contact surfaces of air break switches which are left closed for long periods oxidize more rapidly than if operated occasionally, which oxidizing causes the

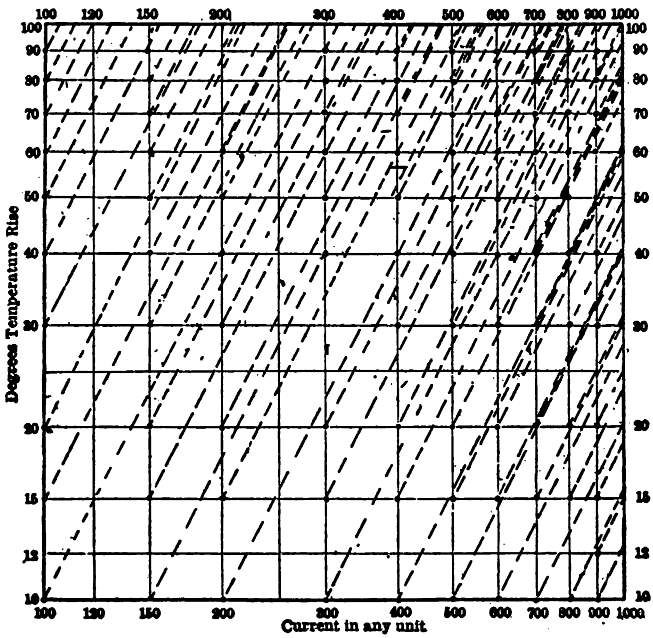


FIG. 5

switch to reach a higher temperature. When this temperature reaches a certain point, the rise becomes cumulative, sometimes resulting in burning up the switch. Experience indicates further that if switches are loaded to their rating, excessive temperatures

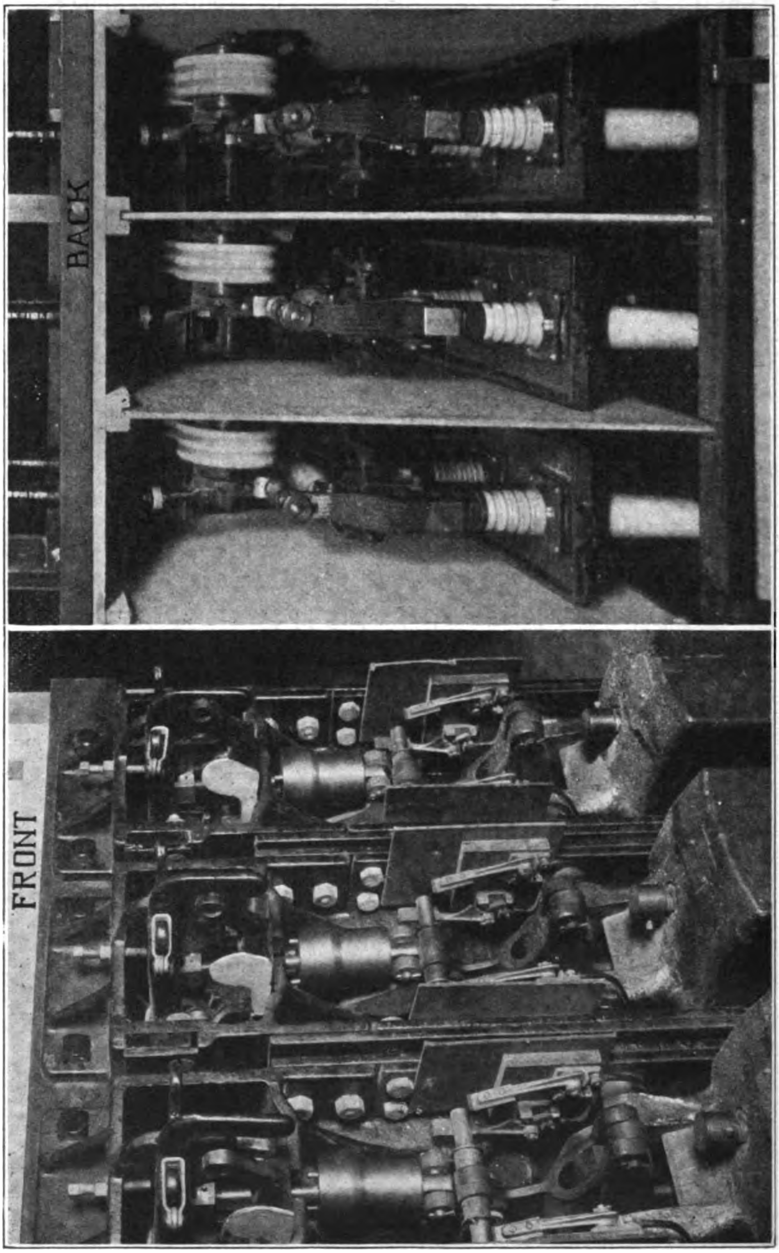


Fig. 6

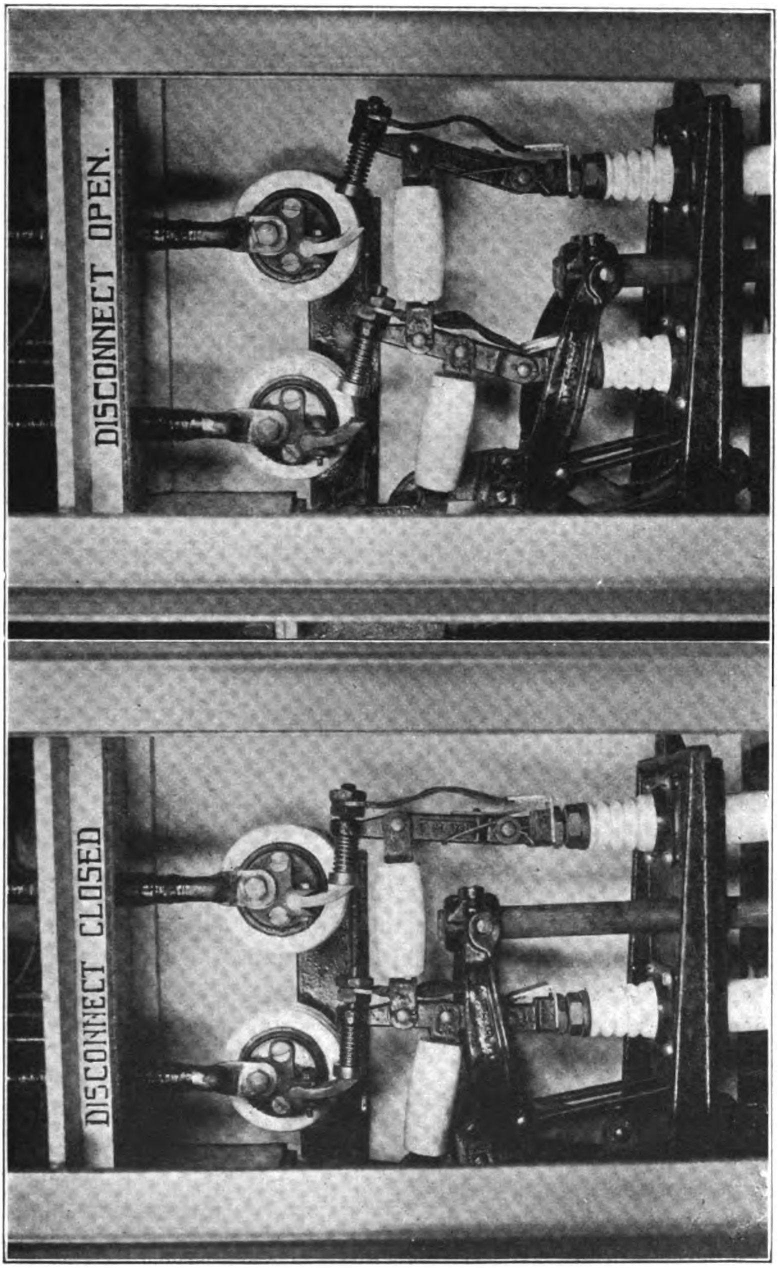


Fig. 6-A

are frequently observed within an unreasonably short time after installation, and this has led a number of operating companies to select switches with much larger ratings than the loads which they expect to carry.

This is an undesirable situation and it is recommended that inasmuch as the present temperature rise is 30 deg. above air at 40 deg., the A.I.E.E. Standardization Committee give consideration to reducing the permissible rise so as to provide a greater factor of safety in the rating than there is at present. One large manufacturer gives ratings at 20 deg. rise as well as at 30 deg., and another rates at 30 deg. and uses a conversion factor for determining the capacity at other temperature rises. A table of such factors was published in the *Electrical World* of January 11, 1908, and is reproduced in Fig. 5.

Automatic Air Disconnective Switch

One member company has developed an automatic air disconnective switch for use with oil circuit breakers. This switch opens slightly after the contacts in oil have opened, and on closing makes contact slightly in advance of the contacts in oil. The development was prompted by a desire to obviate the accidents such as have occurred all over the country with the manually operated air disconnective switches. Fig. 6 shows photographs of such a switch.

Current Transformers

Current transformers have definite limitations as to what they will stand thermally and mechanically under short circuit conditions, and, in view of the many failures which have occurred, it is recommended that member companies investigate their installations in order to make sure that the current transformers installed are adequate in the above respect.

One member company reports the installation of 400-ampere single turn current transformers, having a satisfactory accuracy down to about 100 amperes. These have an actual current carrying capacity of 2000 amperes. This is considerably better than has previously been obtained with any type of single turn current transformer. Such single turn transformers can

readily be made with a comparatively high factor of safety, both as to heat capacity and mechanical strength.

Sub-Committee

A H Lawton, *Chairman.*
L L Elden,
H L Fullerton,
A S MacDowell,
A A Meyer,
J F Neild,
F E Ricketts,
N Stahl,
R F Schuchardt,
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REPORT OF SUB-COMMITTEE ON TRANSFORMERS

The results of this Sub-Committee's work are given in the Transformer Standards booklet accompanying this report. The modifications made in the previous booklet as a result of this year's work may be briefly summarized as follows:

The Standards on Sizes, Voltage Ratings and Taps have been revised, brought up-to-date and extended to cover three-phase transformers. The work of the Transformer Sub-Committee of the Electrical Apparatus Committee has been carried on in close cooperation with a similar committee of The Electric Power Club, representing the manufacturers. This has resulted in coordinating the efforts of both operating companies and manufacturers toward perfecting standards acceptable to all the interests involved.

The Transformer Standards have been extended to cover three-phase distribution transformers in sizes of 200 kv-a. and below, and three-phase power transformers in sizes above 200 kv-a. as shown in Tables III and IV in the booklet. The single-phase sizes have been extended to include the 6667, 8333 and 10,000 kv-a.; the three-phase sizes previously standardized, extended to include 20,000, 25,000 and 30,000 kv-a. capacities.

Outdoor construction has been standardized for all single-phase, oil-immersed, self-cooled distribution and power transformers listed in the standards, and for all single-phase distribution and power transformers where the high voltage rating is identical or higher than the standard low voltage rating listed in the Transformer Standards.

Outdoor construction will also be standardized for all self-cooled, three-phase distribution and power transformers for lighting and power service the ratings of which are equivalent to the single-phase ratings mentioned above.

The Committee considered the advisability of establishing standard transformer voltage ratings for operating on voltages above the 33,000-volt class, which is the highest rating listed in the standards, and the following voltages were suggested: 44,000, 66,000, 88,000, 110,000, 132,000, 154,000 and 220,000. Discussion is invited on these proposed standards and the Committee will be guided by opinions expressed on standardizing ratings.

The Standard Lead Markings for Transformers have been improved by supplementing the typical diagrams by an indication of polarity and by indicating the relative position of taps.

In the 1918 report the Committee recommended that the Subtractive Polarity be made standard for all constant potential transformers, and the little comment that was received during the past year has been largely in favor of this step. This year's Committee sent out to a large number of operating engineers a request for a definite statement on this question and replies show an almost unanimous opinion in favor of the change. The Committee, therefore, definitely recommends, subject to the approval of the Association, that as soon as practicable the manufacturers make all transformers of Subtractive Polarity, and indicate this fact very prominently on the case. The discussion and reasons for this recommendation are clearly set forth on the last page of the Transformer booklet.

Sub-Committee

G L Knight, *Chairman.*
H C Albrecht,
H W Eales,
L L Elden,
A H Lawton,
S J Lisberger,
H H Rudd,
N Stahl,
M O Troy,
H L Wallau.

REPORT OF SUB-COMMITTEE ON SUBSTATIONS

In order to secure necessary data with a view toward summarizing the practices of various companies, both in design and operation of consumers' and system indoor and outdoor substations, a questionnaire was sent to a number of representative member companies operating different kinds of systems.

INDUSTRIAL CONSUMERS' SUBSTATIONS

All companies follow the practice of requiring consumer to secure the company's approval to their substation layouts. As to the equipment used and type of substation employed, practices vary considerably. In a few of the larger cities more or less complete indoor-type substations are used, housed in simple fireproof structure either in the way of addition to the consumer's existing building or in the way of a separate switchboard and transformer vault. (See Figs. 7, 8, 9 and 10 for typical instal-

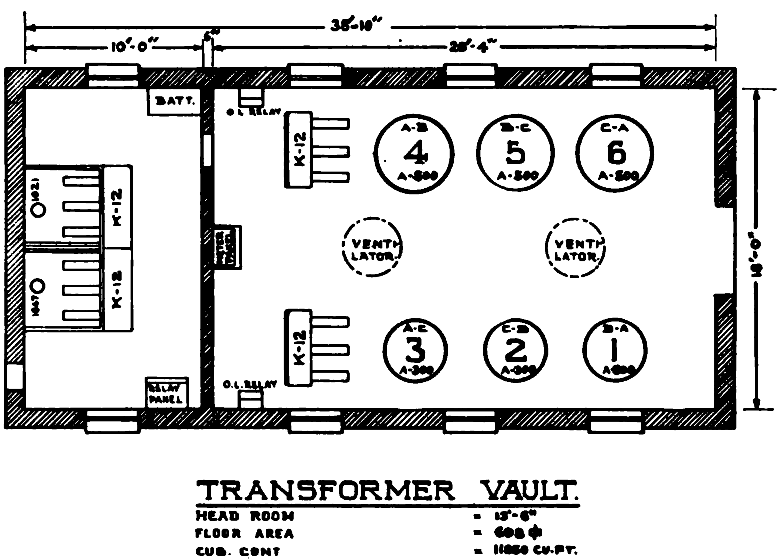

Fig. 7—2400 Kv-a 12000 Volts

lations.) Such a substation is invariably protected with a main line oil circuit breaker of a capacity subject to the company's approval.

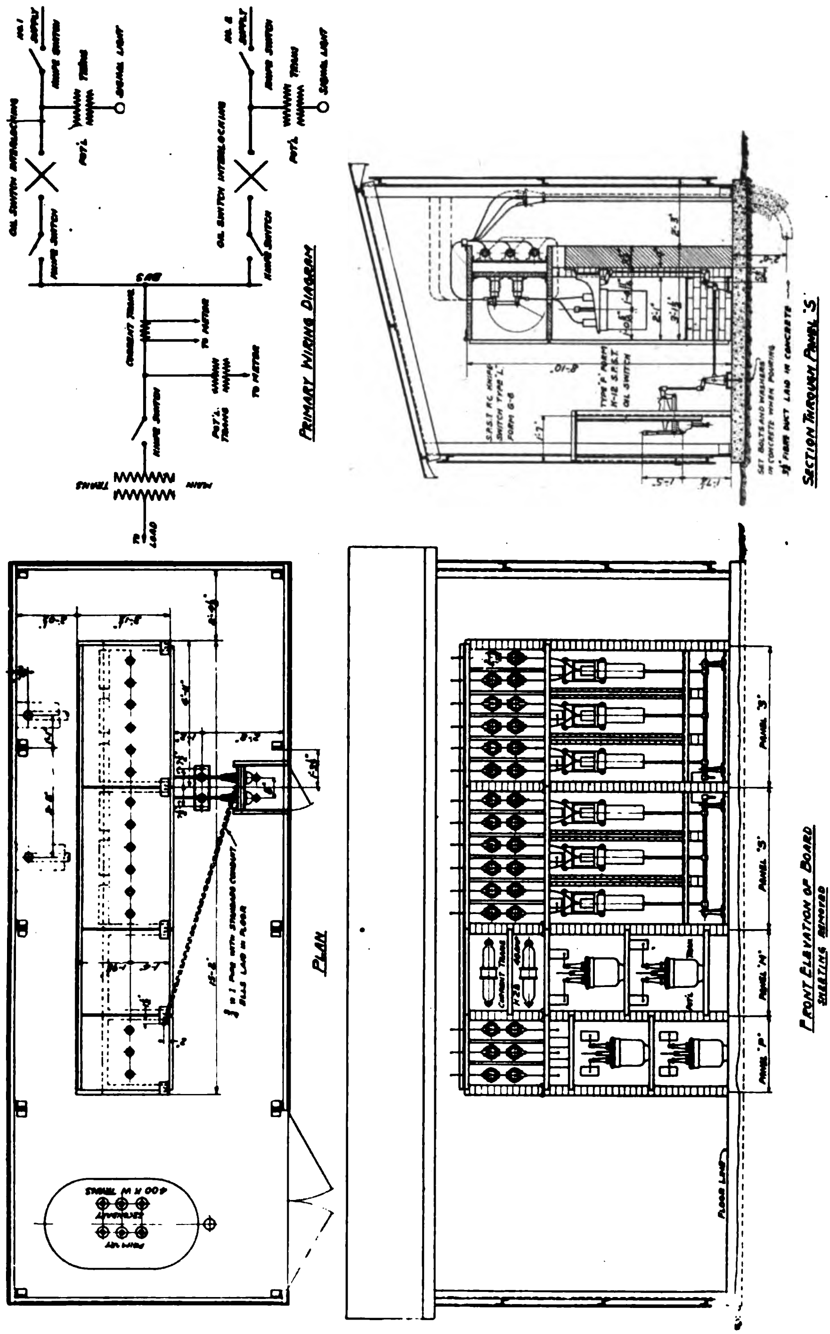
PRIMARY WIRING DIAGRAM
SECTION THROUGH PANEL 'S'
PLAN
FRONT ELEVATION OF BOARD
SHEETING REMOVED

FIG. 8

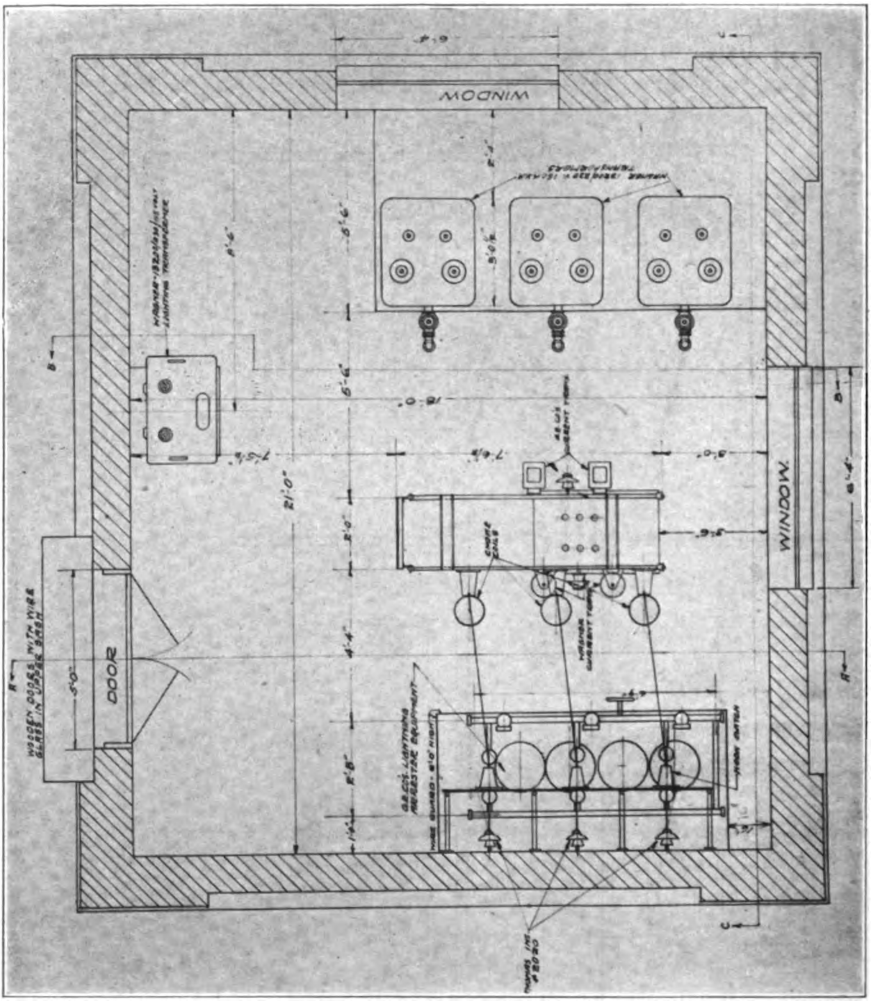

Fig. 9—Industrial Consumer's Substation
450 Kv-a 13200/460 Volt 3-Phase 25 Cycles

In the large cities, while all industrial substations are similar in general characteristics, no two are exactly alike, each job apparently receiving special consideration. However, in most transmission and distribution systems covering an extensive area, a greater degree of standardization exists. In such cases each company usually has a master drawing showing standard layout of various size substations, giving in tabulated form dimension

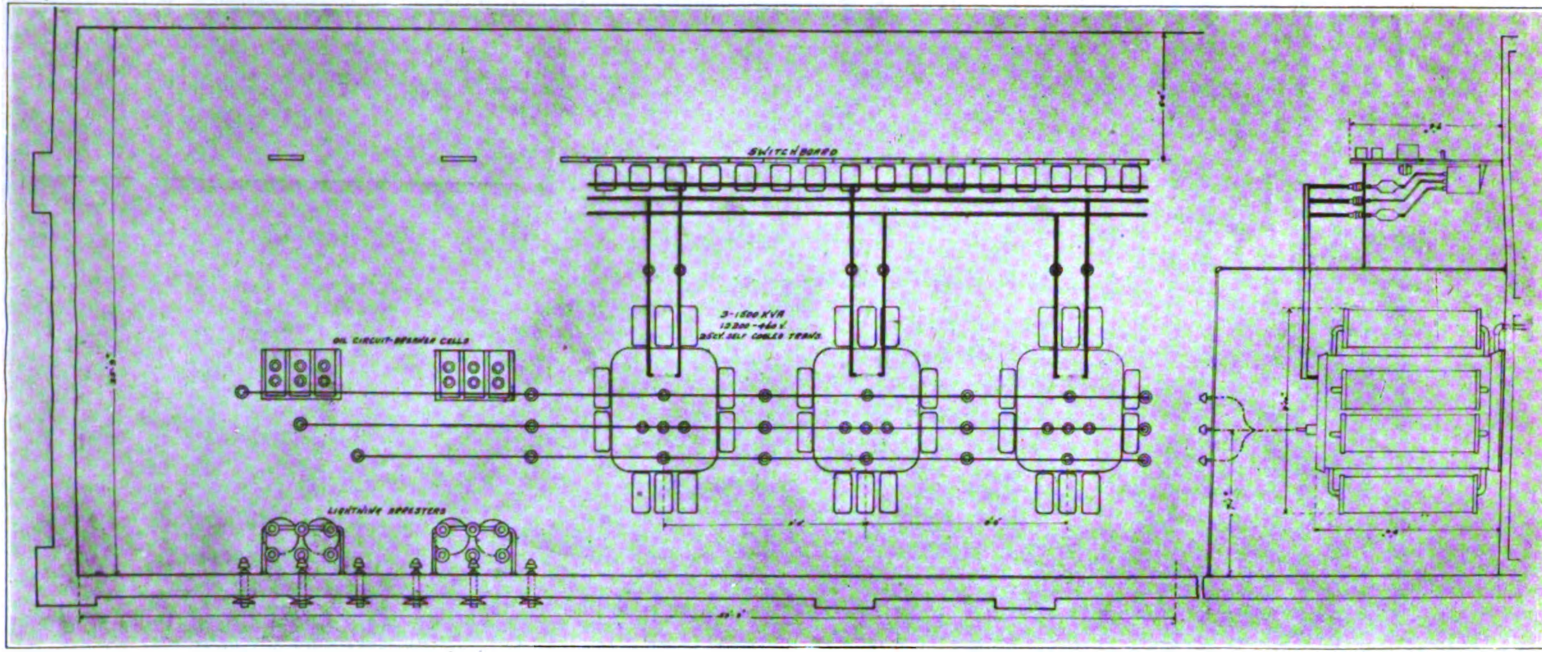

Fig. 10—Industrial Consumer's Substation
4500 Kv-a 13200/460 Volt 3-Phase 25 Cycles

data for substations of various capacities to which it applies. While each system seems to follow its own ideas on the details, in the main the tendency is toward as simple and inexpensive an arrangement as possible, and invariably toward the use of outdoor type equipment throughout. Some companies prefer to recommend the outdoor type substation wherever practicable.

These conditions are probably due to the extent of the territory covered by the different companies. In the larger cities it is comparatively easy to give close supervision to each job. In the scattered territories, however, this close supervision is not possible, hence it is more or less necessary that a standard design for a given capacity be followed by the construction force.

On outdoor installations some companies use self-contained outdoor metering outfits and report no particular difficulty with them. One company reports so much difficulty due to outdoor metering outfit becoming damaged by lightning that it has abandoned the practice of using these equipments and instead now meters energy on low tension side of transformers on consumers'

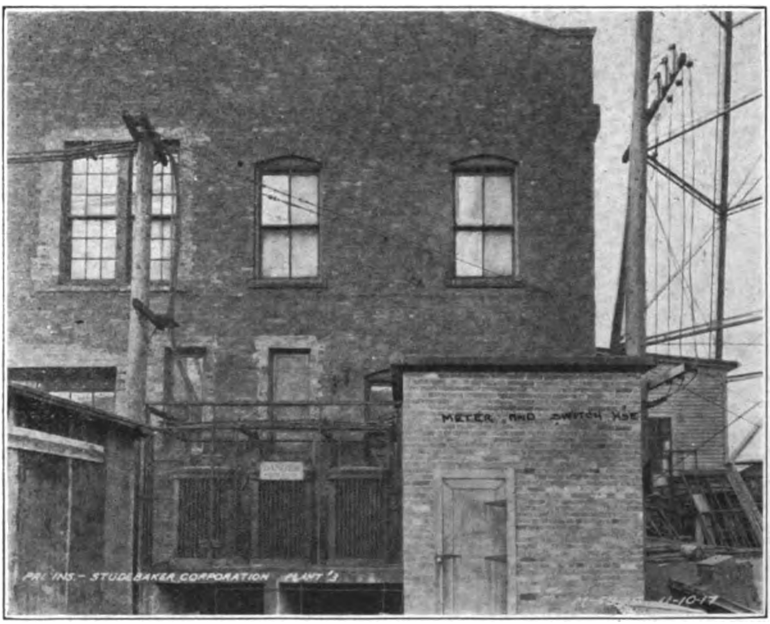

FIG. 11—OUTDOOR PRIMARY INSTALLATION—4600 VOLTS

premises. Some companies construct small meter and switch house to contain primary metering equipment; others mount current and potential transformers outdoors with meter indoors. While a few companies use small wooden sheds to house the meter equipments, the general tendency is to use small, simple houses of either brick or metal, avoiding the use of wood on account of its greater likelihood to take fire from external causes. (See Figs. 11, 12, 13, 14 and 15 for typical installations.)

A majority of companies use single-phase transformers for industrial consumers' substations, probably for the familiar rea-

FIG. 12—OIL SWITCHES SHOWN ARE CUSTOMER'S OUTGOING CKTS.—TOTAL CAPACITY 11000 KW., 4600 VOLTS

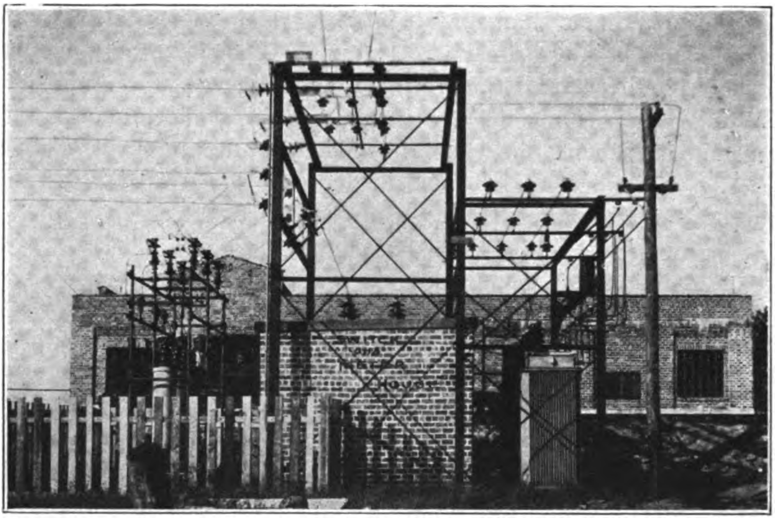

Fig. 13—1333 Kv-a, 33000/2300 Volts—60 Cycles, Outdoor Substation at Coal Mine

son that in the event of failure of one unit the remaining two may be operated in open-delta. As testimony to the reliability of the modern transformer, however, and also as indicative of the probable lower cost, greater simplicity and smaller space requirements of such substations, particularly in voltages of 13,200 and below, there is a noticeable tendency toward the use of three-phase units. In some cases the installation consists of two three-phase combination oil and water-cooled units, so proportioned that both units operating without water will readily carry the load; each unit, however, having a capacity when operating with water 50 per cent in excess of its rating without water. (See Figs. 16 to 20a inclusive, for typical installations.) Fig. 16 shows 1000/1500 kv-a., 13,200-volt, three-phase, 60-cycle substation using combination oil and water-cooled transformers. Fig. 17 shows one company's standard arrangement for 33,000-volt substations 900 kv-a. and above. Fig. 18 shows dimensions of 1333 kv.-a., 33,000/2300-volt. three-phase, 60-cycle outdoor sub-station with one spare transformer unit, outdoor lightning arrester, but with indoor oil circuit breaker and metering equipment for supplying power to large coal mine.

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FIG. 13

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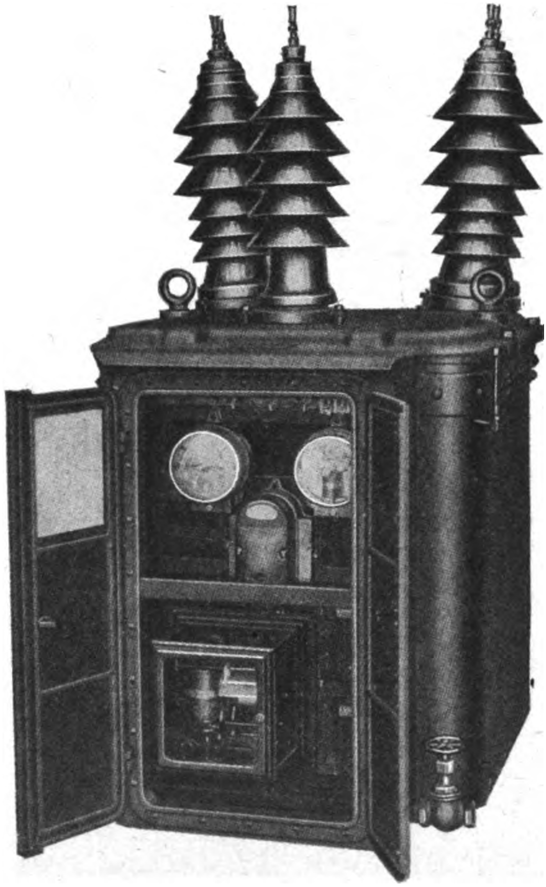

Fig. 15—33,000-Volt, 3-Wire, 3-Phase Metering Outfit Containing Type P Demand Indicator (Printometer) Equipment. Type D-6 Polyphase Watthour Meter and Type C-4 Curve Drawing Power Factor Indicator

The time allotted for the preparation of this report has been too short to permit of assembling cost data on these substations. From discussion with various member companies it is believed that such a study will prove quite profitable. The costs discussed show a wide discrepancy in different localities on jobs of the same general type. A complete study of specifications for substations with costs will no doubt aid materially in pointing out the most economical construction arrangement consistent with reliable service.

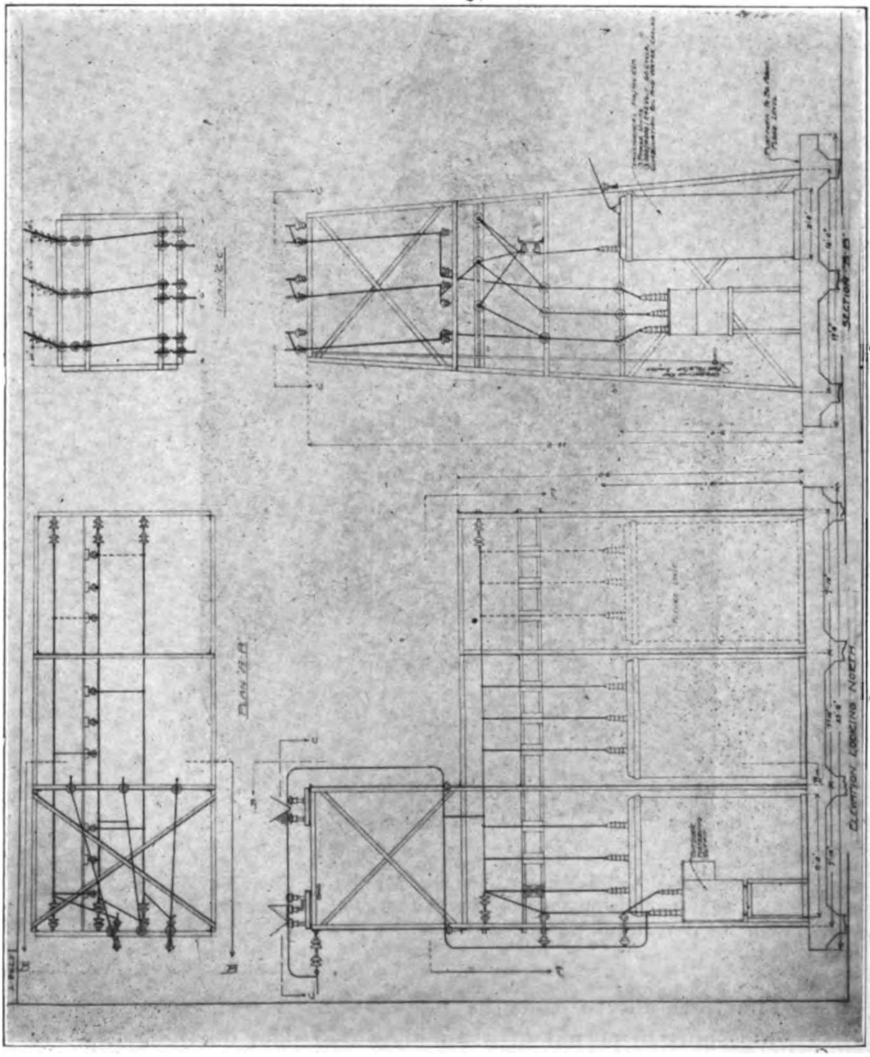

Fig. 16—Industrial Consumer's Substation
1000/1500 Kv-a 13200/4000 240 Volt 3-Phase 60 Cycles With Outdoor Primary Meter

With respect to overload protection, practice varies widely. Many companies protect the entire substation with oil circuit breaker and some with fuses, with no selective overload protection for individual units, while others, in addition, use fuses with individual transformers. One company uses an automatic high voltage air circuit breaker with overload trip coils on each pole

of the switch to protect entire substation. This company reports a large number of such automatic switches in operation on circuits of 44,000 volts and lower, and a few on 110,000-volt circuits; and states that the switch is here to stay and will make itself felt in the design of this class of substation. (See Fig. 21

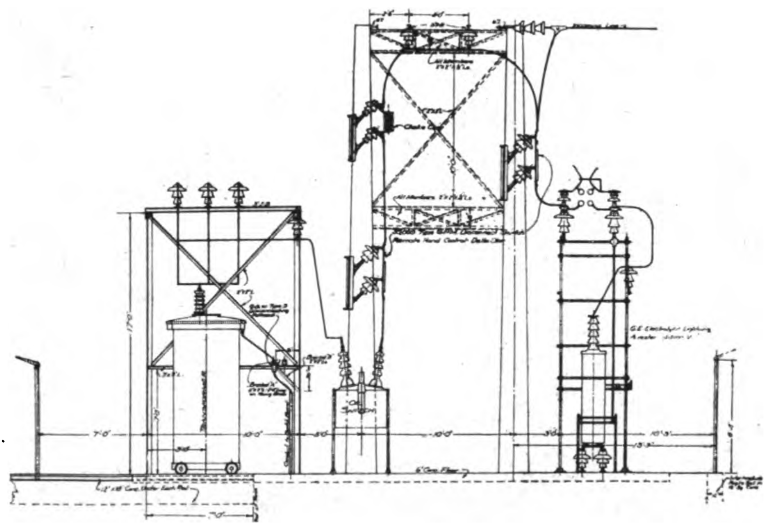

FIG. 17—OUTDOOR SUBSTATION
900-3000 KV-A 33000/2300 VOLTS 3 PHASE 60 CYCLES WITH OIL CIRCUIT BREAKER AND ELECTROLYTIC ARRESTER

for appearance of a 100-ampere, 45,000-volt, triple-pole, single-throw switch with series overload trip on each pole.) One company uses no overload protection of any description on the high voltage side of 11,000-volt, 22,000-volt, or higher voltage substations, treating the transformer as part of the line. The overload protection is provided usually in the form of an automatic oil circuit breaker on the low tension side of equipment.

POWER COMPANIES' SYSTEM SUBSTATIONS

Direct Current:

While seven direct current railway substations, 1000 kw. and above, and over thirty, between 300 kw. and 600 kw. capacity, have been in automatic operation for some time (not including one 3000-kv-a. synchronous condenser and one 1500-kw. hydro-

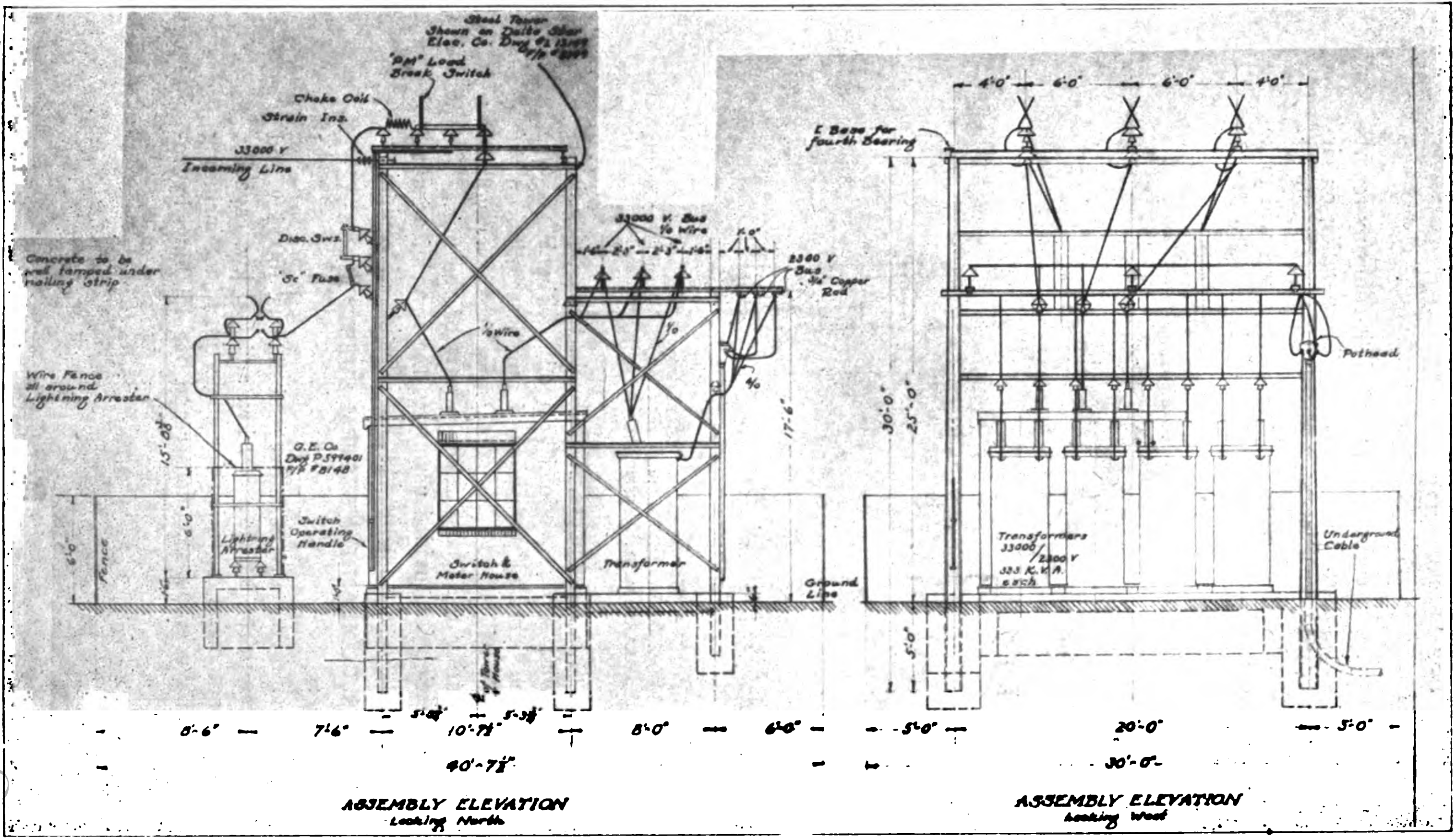

Fig. 18—Substation at Coal Mine
1333 Kv-a 33000/2300 Volts 3-Phase 60 Cycles
With Indoor Oil Circuit Breaker and Meter

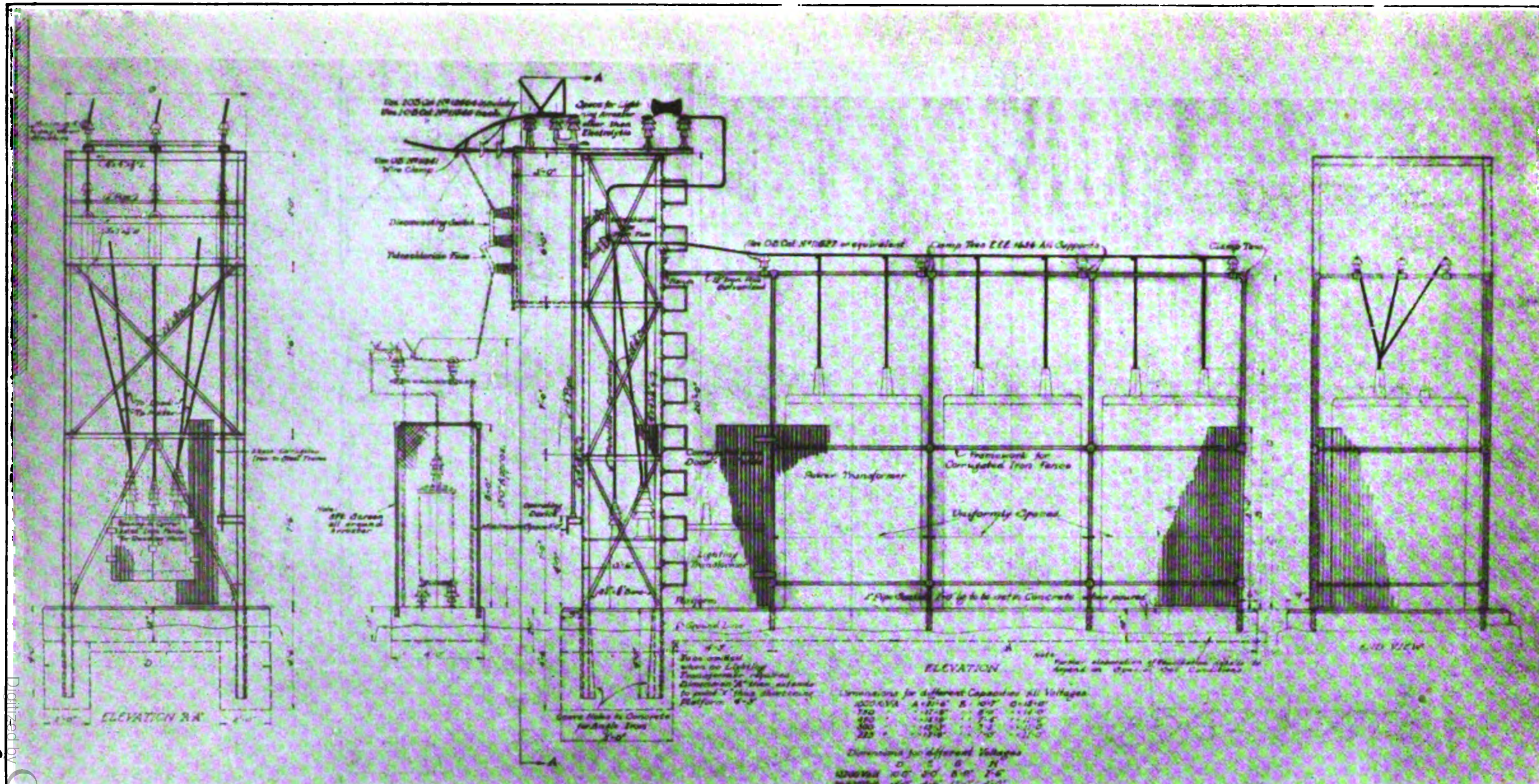

Fig. 19—Industrial Consumer's Substation

225/1000 Kv-a $\frac{26400}{13200} / \frac{460}{230}$ Volt 3-Phase With Outdoor Primary Meter

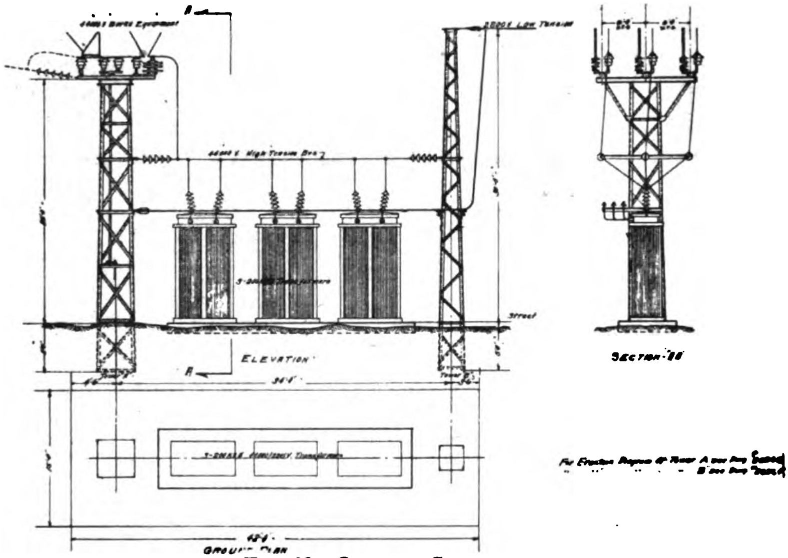

FIG. 20—OUTDOOR SUBSTATION
600 KV-A 44000/2200 VOLT 3-PHASE 60 CYCLES

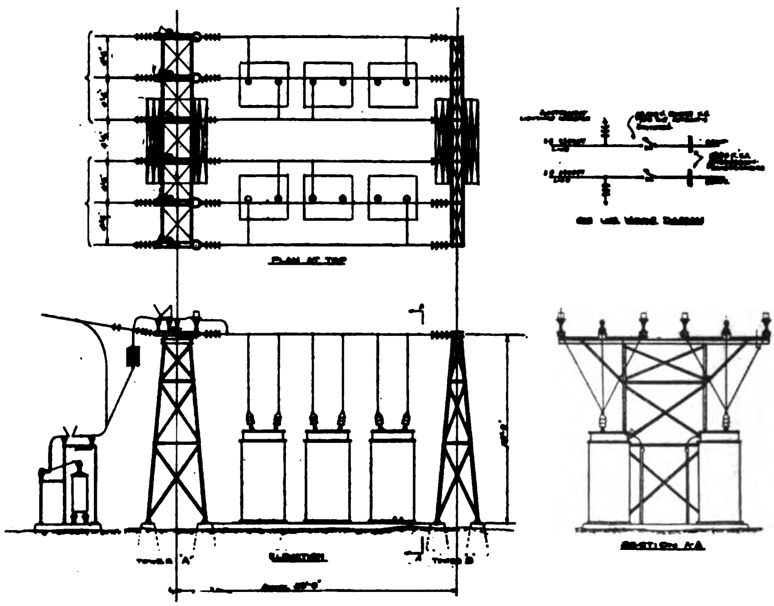

FIG. 20A—OUTDOOR SUBSTATION
4000 KV-A 33000/2300 VOLTS 3-PHASE 60 CYCLES
TWO INCOMING LINES AND TRANSFORMER BANKS

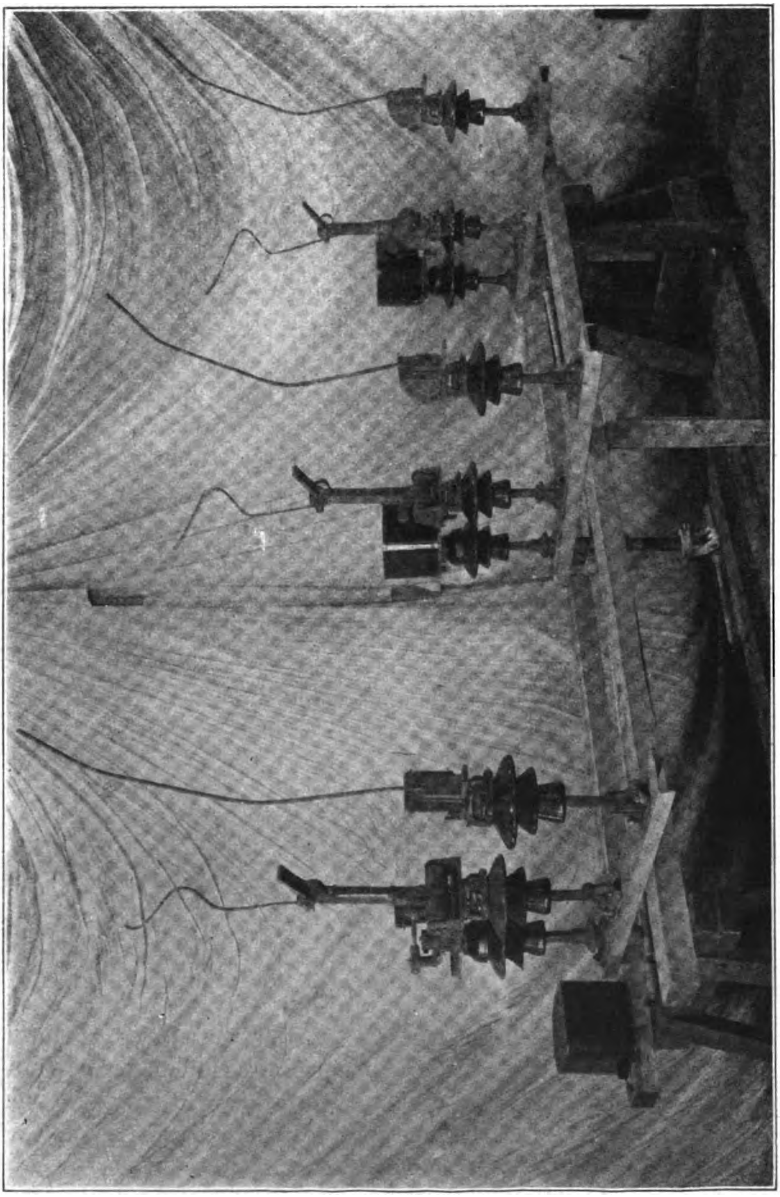

Fig. 21

electric generating plant which operate entirely automatically) (see *Transactions* A.I.E.E. 1918, pp. 497-507), only one lighting company reports substations operating semi-automatically on 115/230 volt direct current network. This company has had five 500-kw. rotary converter substations successfully operating semi-automatically for some time. Each substation is located on the fringe of the 115/230 volt direct current system and is started and stopped remote controlled from other substation as the load demands, the voltage being controlled by induction regulators installed at the main substation.

It is interesting to note, however, that in answer to the question: "If you have no automatic alternating current or direct current substations in operation, do you consider the idea practicable as applied to moderate capacity substations?"—almost without exception all answers were in the affirmative.

From conference with manufacturers, we are justified in venturing the opinion that provided any company desires to operate automatically a substation supplying a 115/230 volt direct current network, the equipment can be procured. Study of each case will show whether the expense of adding the necessary control equipment is justified. (See attached photo Fig. 22 for motor-operated

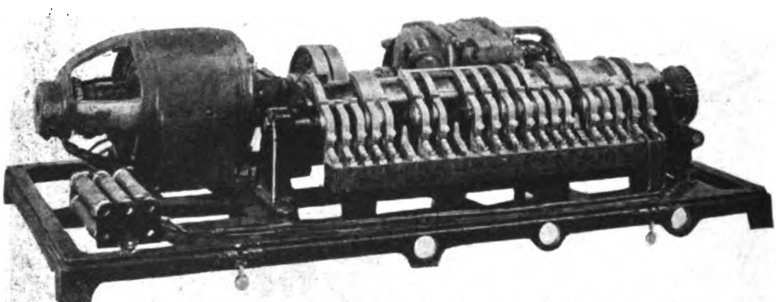

FIG. 22—MOTOR OPERATED DRUM CONTROLLER FOR AUTOMATIC SUBSTATION

drum controller which governs the starting operations of automatic station, and Fig. 23 for appearance of switchboard controlling automatic 600-volt railway substation with two 300-kw. rotary converters.) A bibliography of the automatic railway substations is included at end of report.

Considerable discussion has arisen, particularly during the

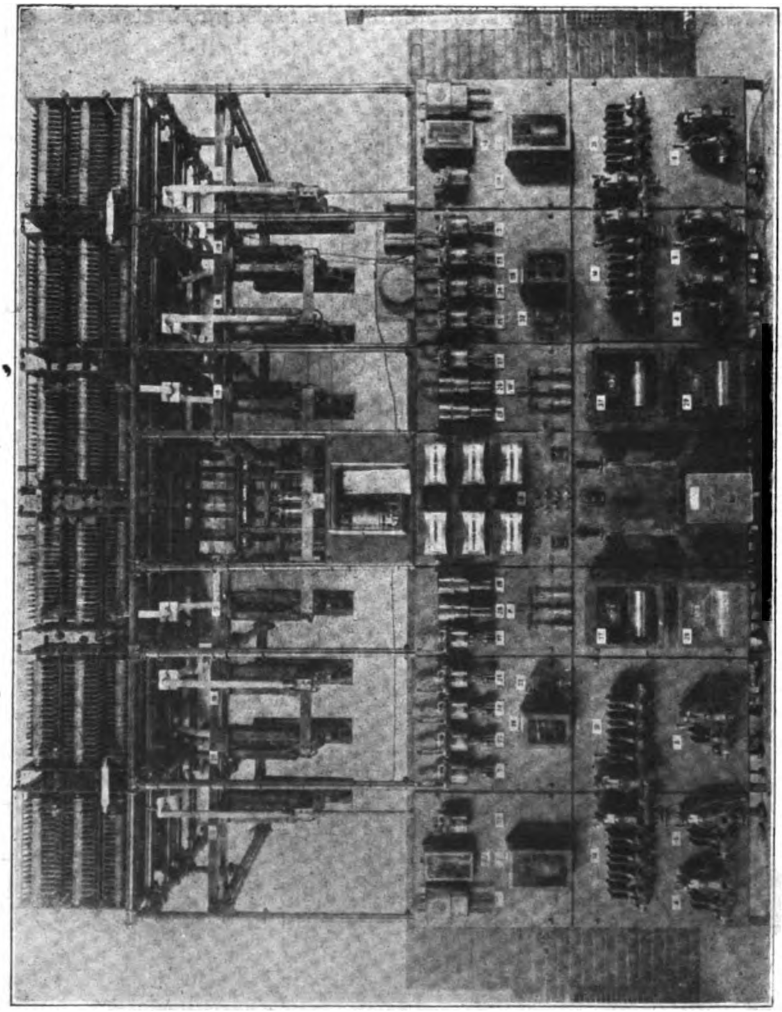

Fig. 23—Automatic Railway Substation, Rhode Island Company
Control Panels and Load Limiting Equipment for Two 300 Kw., 600 Volt Synchronous Converters—Oakland Substation

past two years when all equipment and lines were loaded as no one thought possible previously, regarding the per cent reserve capacity in converting equipment which should be carried by different systems (1) with respect to individual substation peak; and (2) with respect to season peak. Replies to this question indicate that most companies aim to keep a reserve in each substation equivalent to the capacity of the largest unit. The actual

reserve capacity on systems covered by the questionnaire showed the percentage to run from 15 to 33 1/3, not including storage batteries.

With respect to setting an upper limit on the capacity of rotary converters, one company believes that under present conditions it is probable that sizes larger than those now in use with 4000-kw. rating (but with continuous carrying capacity of 5200 kw.) would not be needed. One company fixes a limit of 3500 kw. (35 deg. cent. continuous rating) in rotary converter capacity, basing this on the limiting capacity of one radial feeder. Other companies, most of which use smaller size units than above, have fixed no upper limit.

With respect to the choice of frequency, it is significant that wherever possible the preference for extensions is to use 60-cycle machines, and it is only by companies where the present 25-cycle load and the generators and transmission systems interconnected with them show a preponderance of equipment of that frequency that additional 25-cycle equipment is still preferred. No objection is raised to the use of 60-cycle synchronous converters as

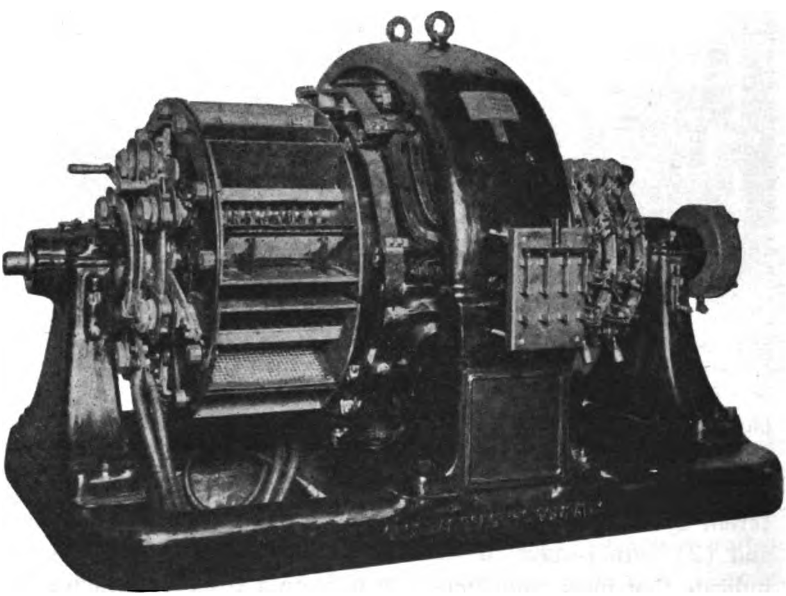

Fig. 24—500-R.P.M., 1200-Kw., 600-Volt Synchronous Converter Showing Flash Barriers Protection

such, though reports indicate that these machines, particularly when supplying 600-volt railway load, are much more sensitive as to flashing than 25-cycle units, but the damage due to flashing is less. The conditions of service, no doubt, have much to do with this trouble. It is expected that flashguards, high speed circuit breakers and improvements in design will make the 60-cycle synchronous converter operate on a par with the 25-cycle machine in all capacities. (See Fig. 24 for appearance of 60-cycle synchronous converter equipped with flashguards.)

There seems to be no definite preference as to type of transformers used with rotary converters, air blast, oil cooled and water cooled units being used, sometimes all three types by the same company, depending upon conditions of installation. While one company builds a dam around oil cooled transformers sufficient to trap all the oil of the unit, there are no reports of a fire started by such unit. Sand and Pyrene are provided to fight possible fires in transformer units, and in case of air blast units one company provides dampers with sprinkler system type of fire fuses, permitting dampers to shut in case of fire. The damper also is arranged when closing to shut down the blower motor and ring an alarm bell or light signal-light in switchboard operator's room. One large company uses three-phase water cooled transformers so designed that, with water turned off, unit will operate at half capacity.

Remote controlled electrically operated direct current circuit breakers are very generally used on large rotary converters. In a few cases remote controlled electrically operated alternating current starting switches are used. (See Fig. 25 for 8000-ampere, motor-operated, double-throw, remote controlled starting switch used with 2000-kw. rotary converter.) No reports were received, however, indicating that any company had any substation or section of substation provided with remote controlled electrically operated direct current feeder switches.

With regard to ventilation of large rotary converters, most companies depend upon good ventilation of substation room only. One company operating a number of large rotary converters in basement substations depends upon combined pressure and exhaust air system for ventilation, and has considered partial housing of the machine for artificial ventilation. One company re-

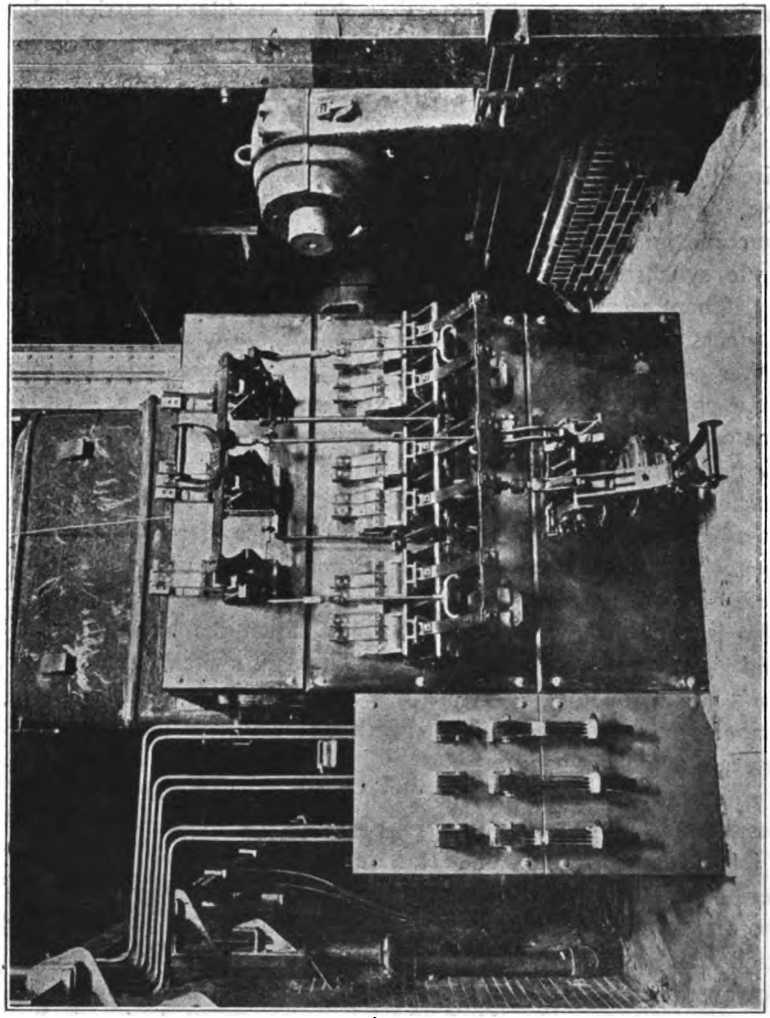

Fig. 25—8000-Amp., Motor-Operated Switch

ports a simple and comparatively inexpensive scheme of blowing cool air up through a 2000-kw. booster type rotary converter. With this machine an air-blast transformer is used. Leads between transformer and rotary converter are in conduit, transformer being about 10 feet from rotary converter. A few spare ducts were added to the conduit, which terminates in a header under transformer. The air discharge from blower divides in this

header, part going up through the transformer and part through the conduit. At the machine à baffle is used, so that part of the air follows the cables, ventilating them and blowing up through the booster of rotary converter, the remainder of air passing up around rotary converter armature. Blowers giving approximately 1½-oz. pressure, as now provided with air-blast transformers for rotary converter equipment, should have ample capacity for both purposes if this scheme is used.

Where converting equipment is operated from a large interconnected alternating current transmission system, some companies using relatively small size converting equipment prefer motor-generator sets to rotary converters. Companies using large converting equipment, 2000 kw. and above, prefer rotary converters on account of higher efficiency, though they recommend a few motor-generator sets with synchronous motors, particularly where power factor correction of the system is desired.

A new departure in rotary converter design has been reported which may be of interest. The equipment consists of a three-unit set of two ordinary 1330-kw. synchronous converters operating at 900 rev. per min., including a revolving field booster of sufficient capacity for both machines. The three units will be direct connected, comprising a four-bearing set, all mounted on a common base, the booster being located between the two middle bearings. The couplings and booster rotor are of such design as to permit disconnection of one converter armature, leaving the other one free to operate with the booster should accident to first one make this necessary. The booster also may be disconnected, leaving both converters free to operate without means of voltage regulation. The booster is provided with two separate armature windings and the transformer is also arranged with two distinct secondary windings, so that the three-unit equipment may be operated without any electrical connection between the two units on the alternating current end. Their performance, therefore, will be that of two separate units operating at 900 rev. per min.. Starting the entire unit will be accomplished by closing transformer secondary switches on 50 per cent taps and then closing high tension oil circuit-breaker. As the set reaches synchronism the field of either machine can be closed and the transformer secondary switch then thrown to full voltage position;

similar process then being carried out with second unit. This sequence of switching would keep inrush of current at a minimum.

This type of unit has the advantage of being much lighter to handle than the ordinary two-unit set, the heaviest part being approximately 40 per cent lighter in weight. The two converters can also be operated in series for railway service. When used for 250-volt service, an increase in efficiency can be obtained at half load by raising the brushes of one unit and operating the other at full load.

Automatic or Semi-Automatic Alternating Current Substations

Some semi-automatic alternating current straight outdoor type distribution substations, and also part outdoor and part indoor substations, of small capacity, are in successful operation. These substations consist of step-down transformers with outdoor induction feeder regulators on 2300-volt distribution circuits. If a fuse blows or oil circuit breaker opens in these circuits, they are hand reset.

Two companies report that they are experimenting with automatic reclosing oil circuit breaker arrangements on feeder circuits. A third company has a small capacity transformer indoor type distributing substation with induction feeder regulators and automatic reclosing oil circuit breakers. These circuit breakers are provided with special control relay equipments designed to reclose a circuit breaker immediately after it opens on overload. Should the circuit breaker reopen, it will again be reclosed for a total of three operations, all of which take place within a few seconds. After three such operations the main control relay opens the circuit of closing coil of circuit breaker, and thereafter it is necessary to close it by hand. Through the successful operation of this equipment, the length of interruption to consumers is reduced. There have been no complaints from consumers on account of rapidity with which the circuit is reclosed. (See photos Figs. 26 and 27 for appearance of type of relays to accomplish above purpose.)

Figs. 28 and 29 are of great interest since they are copies of oscillographic records of actual tests conducted to determine how rapidly oil circuit breakers can be closed by service-restoring relay methods. Fig. 28 shows that, for the particular combination involved in the test, service was restored on the feeder in

FIG. 26—TYPE CV VOLTAGE RELAY ADJUSTED FOR USE AS A LIMITING RELAY

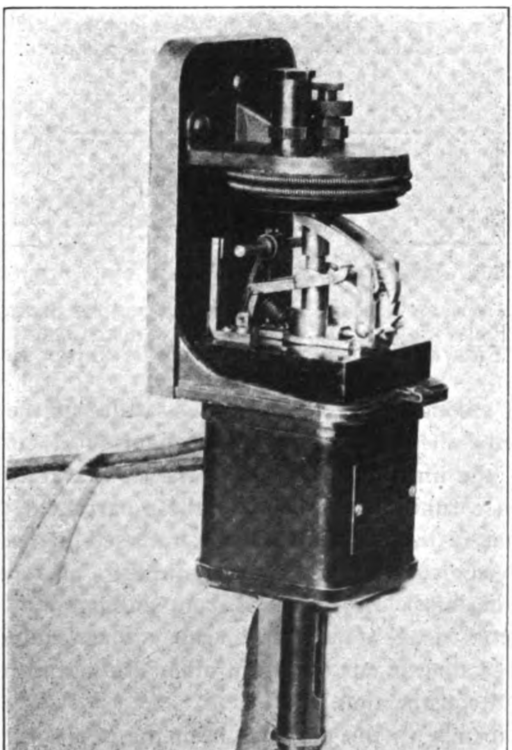

FIG. 27—HESITATING CONTROL RELAY FOR AUTOMATIC RECLOSING OF OIL CIRCUIT BREAKERS

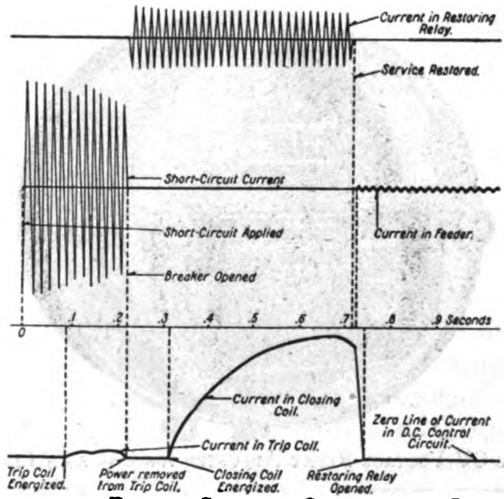

FIG. 28—OSCILLOGRAPH RECORDS SHOWING OPERATION OF SERVICE-RESTORING RELAY SYSTEM ON A TRANSIENT SHORT CIRCUIT

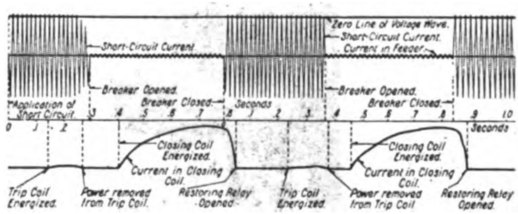

FIG. 29—OSCILLOGRAPH RECORDS SHOWING OPERATION OF SERVICE-RESTORING RELAY SYSTEM ON A PERMANENT SHORT-CIRCUIT
BREAKER IS SHOWN CLOSED TWICE—FURTHER OPERATION NOT RECORDED

72-100 of a second. Fig. 29 shows the nature of the operations to be expected in the case of a permanent short circuit on the feeder until the limiting relay causes the service restoring accessories to cease functioning. During these particular tests it was reported that if the circuit could be reclosed in less than one second, service would be restored in time to prevent induction motors driving most kinds of load from stalling.

Apparatus used in automatic substations should be more liberally rated than is customary in other types, and it should all be of rugged construction.

One difficulty in the past has been the necessity for the installation of a storage battery with necessary attention to charging, etc., for the operation of direct current solenoids or motors

on oil circuit breakers. The development of straight alternating current operated oil circuit breakers will, however, remove this objection. (See photo Fig. 30 for appearance of an alternating

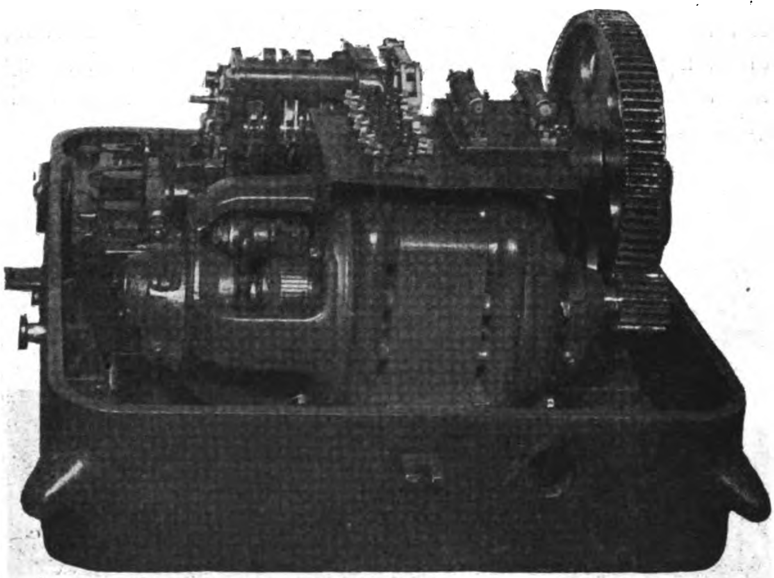

FIG. 30—A. C. MOTOR-OPERATED MECHANISM FOR OIL CIRCUIT BREAKERS

current motor-operated mechanism for oil circuit breakers. It is hoped that a simpler device may soon be forthcoming.)

It seems safe to say that the wider adoption of alternating current automatic substations will tend toward the use of a larger number of smaller capacity substations than has been customary heretofore. The Committee suggests that all member companies give consideration to this subject, if only to the extent of trying out the method in substations operated by attendants.

In substation practice a recent tendency of some large companies is observed in some cases to use oil circuit breakers and cells so arranged that the entire switch and cell or one pole and cell may be removed from the structure and another unit substituted.

Outdoor Substations

The familiar practice of high tension transmission systems

in using outdoor type transformer and switching substations seems to have extended to lower voltage systems. Many central station companies have installed outdoor suburban substations. Where there are no series mercury arc rectifier equipments and few regulators, no building is necessary. If automatic reclosing oil or air circuit breakers come into wider use, it is safe to say that the adoption of outdoor substations will be further extended. (See Figs. 31 and 32.)

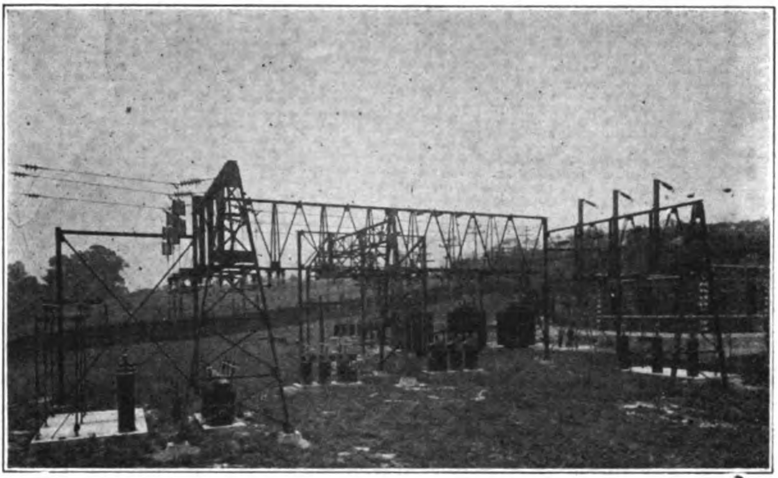

Fig. 31—Outdoor Substation
12500 Kv-a 66000/22000 Volts 60 Cycle

With one exception, companies operating large numbers of outdoor substations report no serious difficulties with the operation of the equipment.

Indoor Substations

With regard to distribution busses in alternating current substations, it still seems to be the general practice to operate all banks of transformers and distribution feeders on one bus with a reserve bus provided. The capacities so connected run from small amounts up to 10,000 kv-a. and in some individual cases considerably higher. As larger capacities are approached, the rupturing capacities of the feeder oil switches may be overtaxed. To avoid incurring the considerable expense of changing all sub-

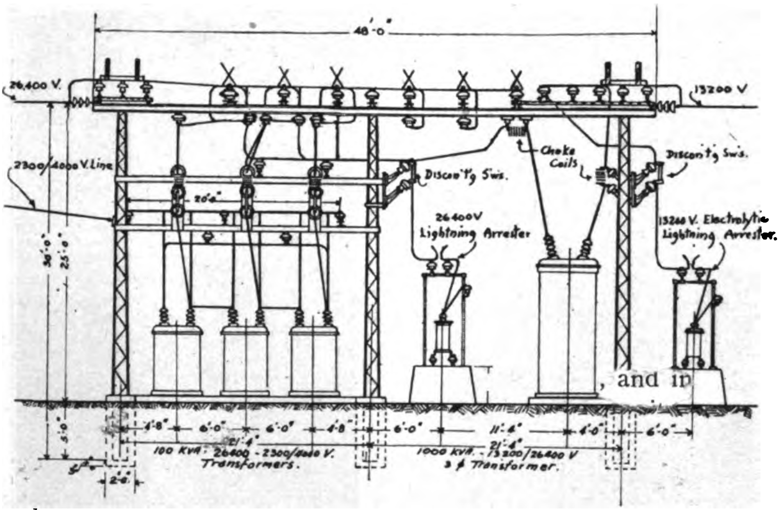

FIG. 32—OUTDOOR SUBURBAN SUBSTATION

1300 KV-A $\left\{\begin{matrix}26400/13200 \\ 26400/2300/4000\end{matrix}\right\}$ VOLT 3-PHASE 60 CYCLES

station switches, as well as possible switch destruction, it seems desirable to consider sectionalizing the bus or operating with reactors between the sections, as has been done in some cases with generator busses. The reactance of new transformers installed in substations should be carefully considered in this connection.

Induction Regulators

A growing preference is apparent for induction regulators with most of the accessories mounted on the regulator itself. In this connection, and especially during the period of scarcity of material and high prices of platinum, attention is called to a discussion by W. D. Coolidge in the 1912 A.I.E.E. *Proceedings,* page 1219, on the possibilities of the use of metallic tungsten for contacts of auxiliary devices such as contact-making voltmeters. This discussion includes practical considerations necessary to render tungsten usable for this purpose. Due to the fact that the induction feeder regulator gets the brunt of the shock of a short-circuit on the feeder, some companies recommend the installation of by-pass electrolytic arrester connected in shunt with the regulator as a protective means. Caution is urged to give regulators frequent inspection to see that the oil is maintained at proper

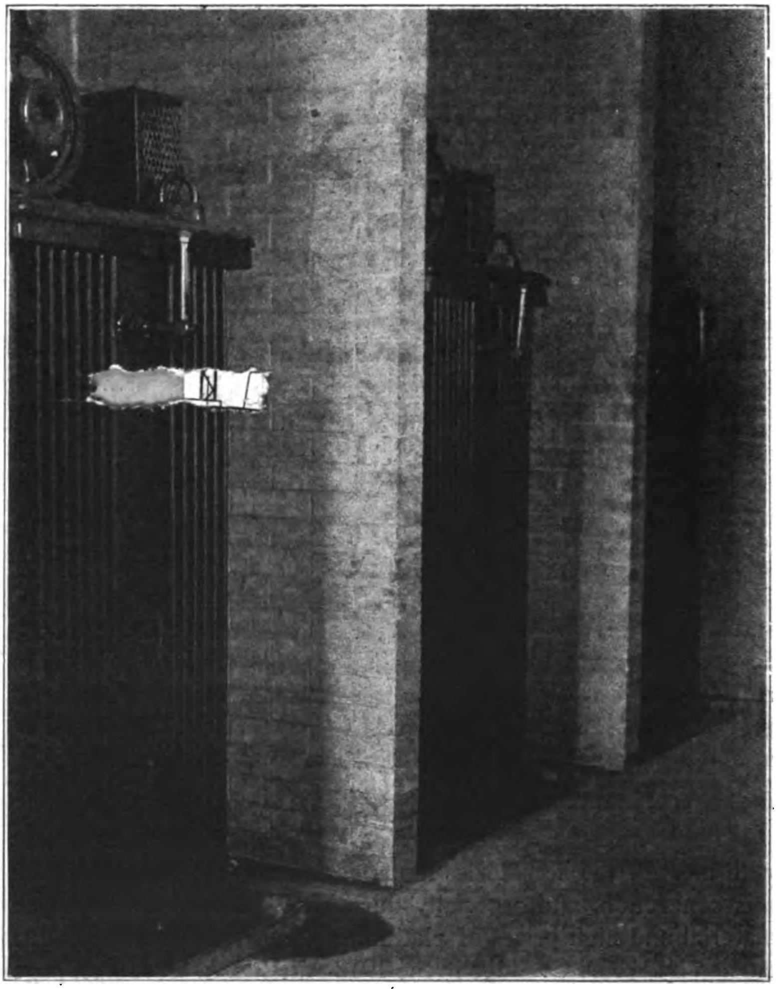

FIG. 33—FEEDER REGULATORS IN FIRE PROOF CELLS

level in order to avoid serious consequences which may result if this is not done. Fig. 33 shows an arrangement of feeder regulators in individual fireproof cells. Due consideration must be given to ventilation where this method of installation is followed.

Transformers—Indoor and Outdoor

The replies on use of three-phase or single-phase transformer units for indoor substations indicate that the trend of

practice, with moderate voltages, is for the larger central station companies to install three-phase units where more than one bank of transformers is generally used. There is no uniformity of practice with respect to method of cooling—i.e., all types, air blast, water cooled, self cooled, and combination self cooled and water cooled, are used. On high voltage transmission systems, and particularly with outdoor types, the practice favors single-phase, self-cooled units. A recent improvement with regard to water cooled units is in having the water pipes brought out of the case at a point well below the level of the oil. This prevents sweating of water pipes in transformer. Brass or copper coils will generally be found preferable to iron coils, and in cases of impure water, brass or copper coils become a necessity.

Subcommittee

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REPORT OF SUB-COMMITTEE ON POWER FACTOR CORRECTION

EFFECT OF POWER FACTOR

For any given alternating current system, the capacity required in generators, lines, transformers, etc., varies inversely with the power factor, and the copper losses in transmission and distribution vary inversely as the square of the power factor.

With lagging power factor, generator excitation increases rapidly, and with decreasing power factors a point is soon reached where further excitation cannot be supplied without exceeding the safe temperature limit of the field winding.

Regulation also is affected by power factor and depends upon the constants of the line.

Generally speaking, the use of motors too large for the load is the most frequent cause of low power factor. Another cause sometimes encountered is the use of motors designed for a voltage lower than the supply voltage.

POWER FACTOR SURVEY

The benefits frequently to be obtained by operating companies from even a slight gain in power factor are very desirable, and it may be advisable for many member companies to undertake a power factor survey of their system to determine its value at the generating plant, at the various substations, at the more heavily loaded industrial circuits and finally at the larger consumers' installations, with a view toward ascertaining whether certain remedial steps should not be considered.

POWER FACTOR CORRECTION

Often considerable improvement in power factor may be obtained by rearrangement of the existing motors and drives, so that the motors are loaded more nearly to capacity. Even in heavy press work, where pull out torque is a governing factor, improvement may sometimes be obtained by this method.

CORRECTION APPARATUS

Where additional apparatus is needed to bring the power factor up to a satisfactory value, the following may be employed:

Synchronous Motors

Slow speed motors of this type are suited for direct connection to compressors, refrigerating machines, and loads of similar characteristics, and have marked advantages in weight and efficiency over corresponding induction motors.

High speed synchronous motors are suited for direct current generator drive and for general industrial drives where the load is reasonably uniform and the starting and stopping requirements not severe.

In addition to doing useful mechanical work, these motors can be used to neutralize in part the reactive component required by inductive loads. Commercial motors of this type built for speeds under about 300 rev. per min. are usually designed for operating at unity power factor, while the high speed motor lends itself more readily to an economical design with capacity for operating at a leading power factor, usually down to 80 per cent at full load and more at lesser loads.

Synchronous Condensers

These machines fall in the same class as synchronous motors but are not designed for mechanical work. Their losses are from 5 to 7 per cent of their rating and they operate at a leading power factor, neutralizing the reactive component of the inductive load to practically the full extent of their rating.

They may also be used to maintain constant voltage at the end of a transmission line, being controlled by an automatic regulator, or they may be arranged to maintain constant the power factor of a given installation in order to meet some contract requirement.

Automatic starting and stopping control devices may now be obtained in addition to the regulator mentioned above.

Static Condensers

This type of apparatus has no moving elements and lends itself to smaller installations in which the load and power factor are reasonably constant and at which attendants are not provided. The device is highly efficient, the losses being approximately 1 or 2½ per cent.

The manufacturers have recently announced a price revision which will make the first cost of this type less for small capacities

at low voltages than the corresponding cost of synchronous condensers, while for the higher voltages the cost will be less than synchronous condensers up to some point beyond 300 kv-a.

About 3500 kv-a. of such apparatus is in use, ranging in size from 50 to 350 kv-a. units. Reports from operating companies on whose circuits static condensers are used are very satisfactory.

Location of Corrective Apparatus

Primarily, it should be located as near as possible to the origin of low power factor, but in certain cases an analysis may show the wisdom of installing corrective apparatus in the company's substations.

Apparatus located on the premises of a consumer corrects from the point of installation back to and including the generators. When located in the company's substation, however, it has no corrective effect on the distribution lines or consumer's transformers.

REFERENCES

A very interesting paper on the effects of power factor on investment and operating costs by C. I. Crippen, Manager Power Sales Division of the Mahoning and Chenango Railway and Light Company, may be found in the March, 1919, Bulletin of the Ohio Electric Light Association.

A bibliography on the subject will be found in the appendix.

Subcommittee

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APPENDIX TO REPORT ON POWER FACTOR CORRECTION

There are submitted herewith some details which illustrate certain phases of the subject not covered by the broad outline given in the main report.

Effect of Unity Power Factor Load

The effect of a large quantity of unity power factor load in maintaining the power factor of a central station's total load at a reasonable value is shown in Fig. 34, which analyzes the com-

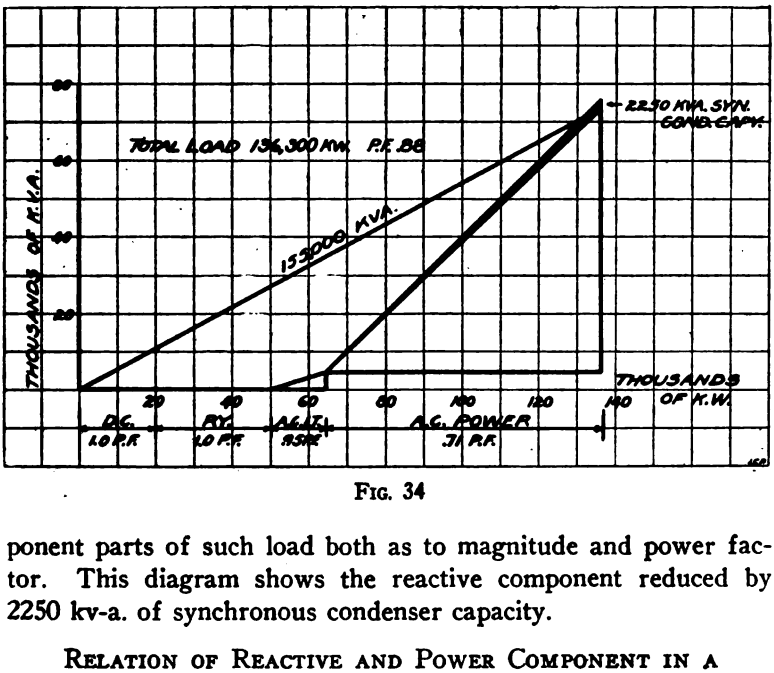

Fig. 34

ponent parts of such load both as to magnitude and power factor. This diagram shows the reactive component reduced by 2250 kv-a. of synchronous condenser capacity.

Relation of Reactive and Power Component in a Synchronous Motor

The problem of prescribing the size of synchronous motor to do mechanical work and at the same time raise some industrial load from one power factor to another is often encountered. In Fig. 35 is shown the relation obtaining between reactive and

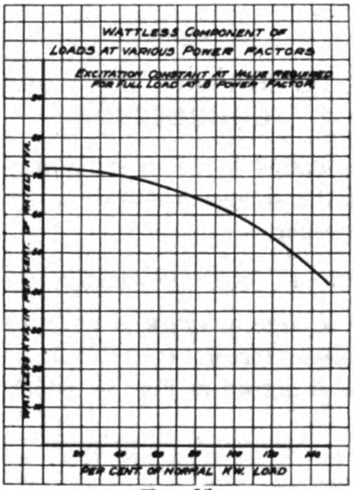

FIG. 35

energy components for synchronous motors designed for 80 per cent leading power factor operation, when excited for full load output at that power factor. This curve is typical and, while individual motors will depart somewhat from this, the variation will not be great. Its use can be best explained by an example:

Assume an existing load of, say, 230 kw., the power factor of which is 75 per cent. The reactive component, which it is wanted to neutralize, then is 202 kv-a. Assume further that an additional load of 150 h.p. is to be taken on and that a synchronous motor for this load is desired to bring the total load power factor up to unity. A reactive component of 202 kv-a. leading is required in the motor. A 150 h.p. motor with an efficiency of 89 per cent has an input with 80 per cent leading power factor of 158 kv-a. and a reactive component (the corrective item) of 60 per cent as shown on the curve, or 95 kv-a. This will improve the power factor only in part and a larger motor is found to be required. If a 300 h.p motor with an efficiency of 92 per cent at half load be installed and the excitation be carried to that point which would correspond to an 80 per cent leading power factor at full load output, the input to this motor at half load will be 306 kv-a. and a reactive component of 69 per cent obtained (as shown by the curve), or 211 kv-a. A slight decrease in field excitation will reduce this component to the amount required.

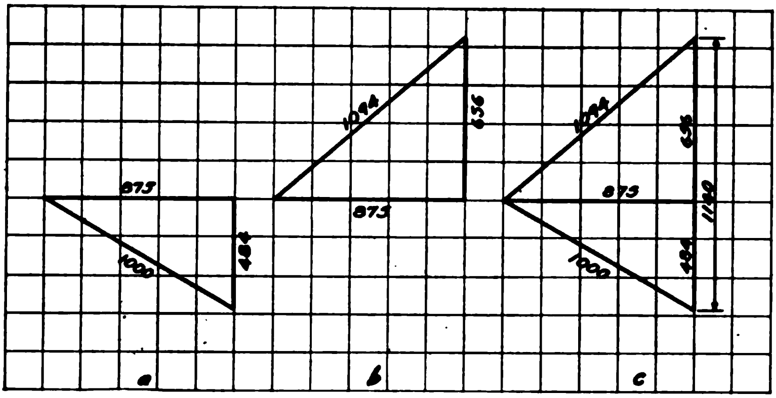
875
1000
484
1094
636
875
1094
636
875
1000
484
1120
a
b
c

FIG. 36

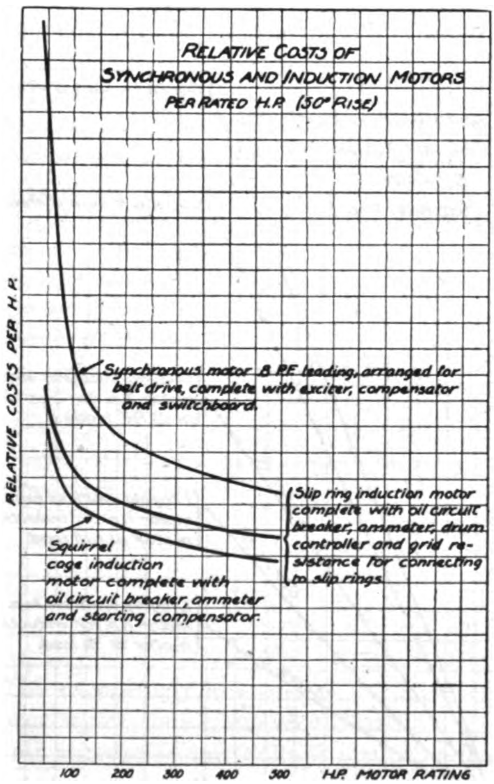
RELATIVE COSTS OF
SYNCHRONOUS AND INDUCTION MOTORS
PER RATED H.P. (50° RISE)
Synchronous motor .8 P.F. leading, arranged for belt drive, complete with exciter, compensator and switchboard.
Slip ring induction motor complete with oil circuit breaker, ammeter, drum controller and grid resistance for connecting to slip rings.
Squirrel cage induction motor complete with oil circuit breaker, ammeter and starting compensator.
RELATIVE COSTS PER H.P.
100
200
300
400
500
H.P. MOTOR RATING

FIG. 37

Benefits to Be Obtained By the Substitution of a Synchronous Motor for An Induction Motor

Fig. 36(a) shows the power component and the lagging reactive component of an induction motor having a power factor at full load of 87.5 per cent. Fig. 36 (b) shows the reactive component of a synchronous motor of the same horsepower rating operated at 80 per cent power factor leading.

Fig. 36(c) shows the benefits resulting to the system by the substitution of the synchronous for the induction motor. Here 656 leading reactive kv-a. are substituted for 484 lagging kv-a., making a total gain equivalent to 1140 leading kv-a. This assumes that the balance of the load has a power factor less than unity and the corrective effect is desired.

Relative Costs of Corrective Apparatus Per Kv-a

Fig. 37 shows the relative costs of synchronous motors and

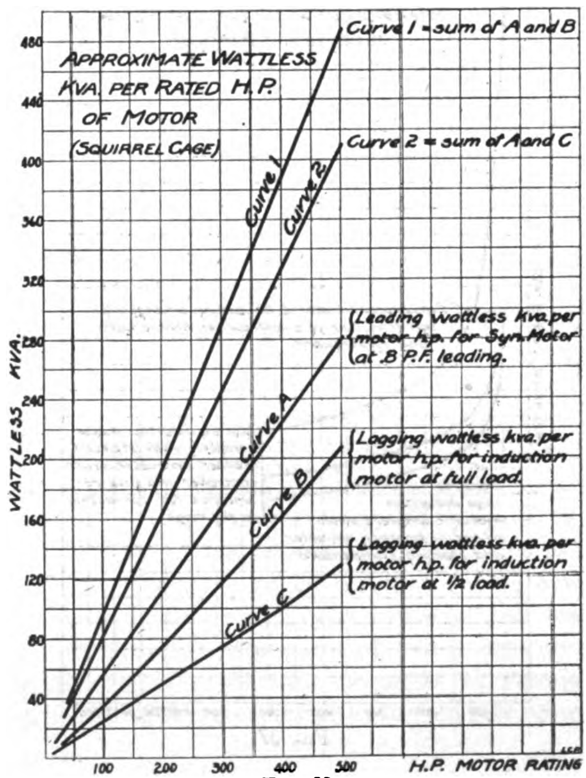

Fig. 38

of slip-ring and squirrel-cage induction motors per horsepower rating of one large manufacturer.

Figs. 38 and 39 show the equivalent gain in wattless component by the substitution of a synchronous motor for induction motor of each type respectively.

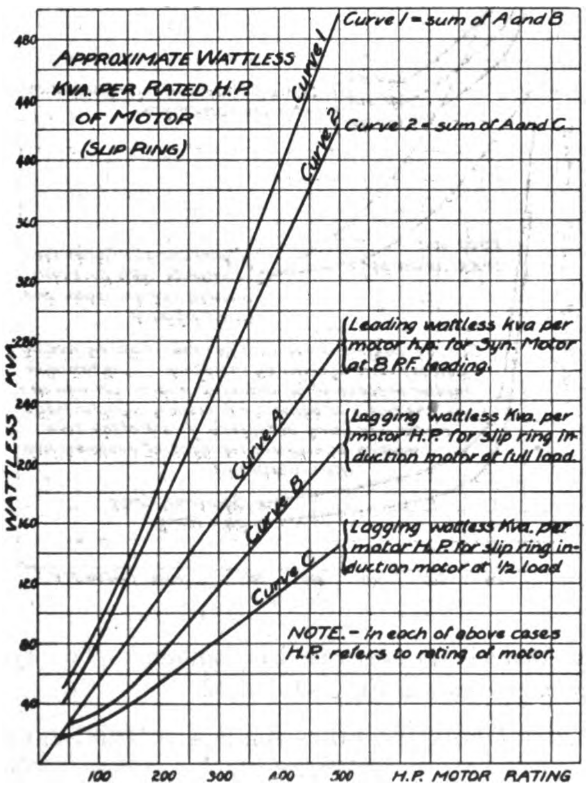

FIG. 39

Fig. 40 shows the relative costs per kv-a. of correcting the power factor by use of static condensers and synchronous condensers, and also by the substitution of synchronous for induction motors. The exceedingly low cost of the latter method of correcting power factor stands out very clearly.

The cost curves for low voltage static condensers have not been extended beyond 250 kv-a. This size is the largest now

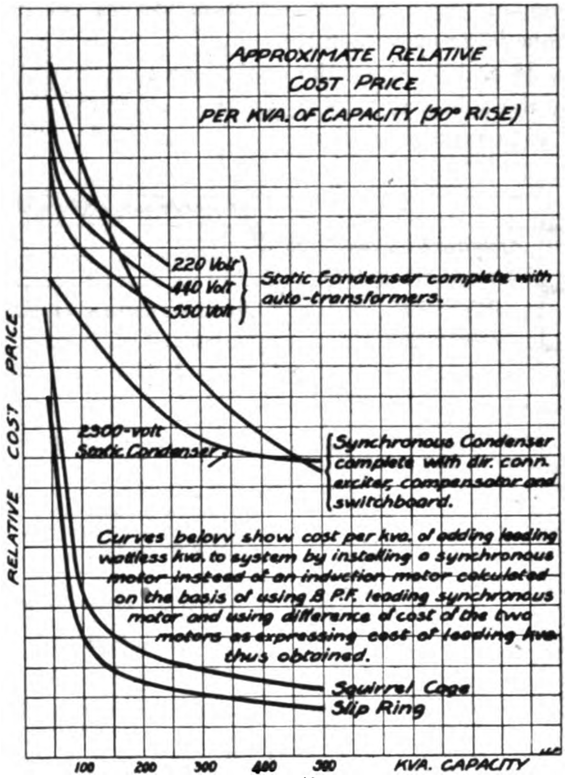

FIG. 40

listed, but there is no inherent size limitation. Two typical installations are shown in Figs. 41 and 42.

COMPARATIVE OPERATING COSTS FOR STATIC AND SYNCHRONOUS CONDENSERS

Fig. 43 shows two sets of cost curves based on 3500 hours during a year's operation, and including fixed charges. The upper set is based on an energy cost twice that in the lower set.

OTHER CORRECTIVE APPARATUS

Oscillating Phase Advancer

This device has been developed to improve the power factor of induction motors having phase wound rotors. It is more effective for low than for high frequency motors, and must be

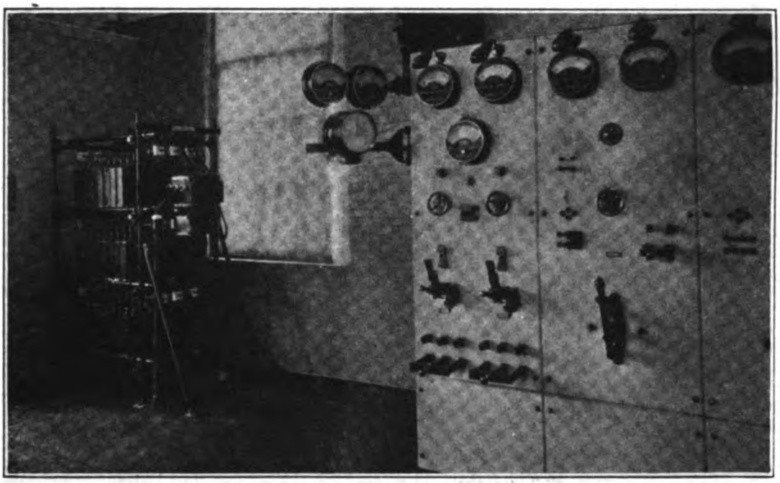

FIG. 41—3-PHASE 60 CYCLE 440 VOLTS 100 KV-A STATIC CONDENSER INSTALLATION AT DOHERTY SILK COMPANY, LAKE VIEW, N. J. (Auto transformer not shown)

designed for use with a specific motor. For complete description see Electric Journal, November, 1918. Fig. 44 illustrates this device.

Rotary Phase Advancer

This device, referred to in the 1915 report of the Electrical Apparatus Committee, fulfills a similar purpose, and is described in detail in the General Electric Review for June, 1914.

TYPES OF LOADS SUITABLE FOR SYNCHRONOUS MOTOR DRIVE

Air Compressors	Line Shafts
Ammonia Compressors	Metal and Rubber Rolls
Centrifugal Pumps	Mixers
Conveyors	Motor Generator Sets
Crushers	Pump Grinders
Fans	Reciprocating Pumps
Frequency Changers	Screw Pumps
Grinders	

AUTOMATIC SYNCHRONOUS CONDENSER SUB-STATION

In the past two years there has been in successful operation an automatically controlled 3000 kv-a., 4000 volt, 720 rev. per

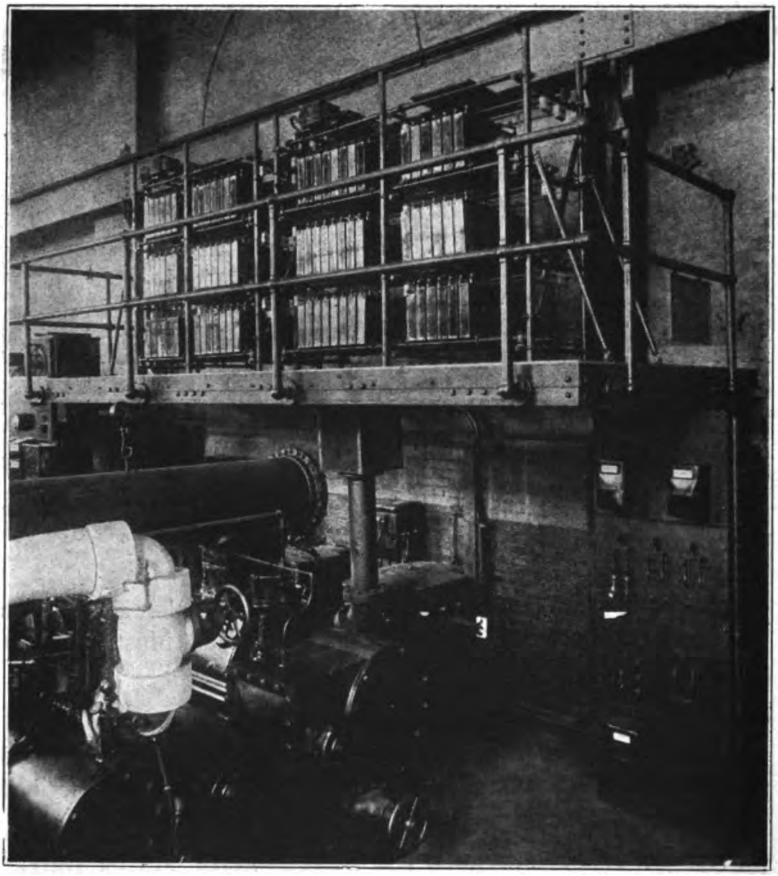

FIG. 42—3-PHASE 60 CYCLE 350 KV-A STATIC CONDENSER EQUIPMENT INSTALLED BY THE NATIONAL ANILINE AND CHEMICAL COMPANY, BROOKLYN, N. Y. (Side View)

min. synchronous condenser connected to the system of the Interstate Light & Power Company (H. M. Byllesby Company) at Hazel Green, Wisconsin.

The generating station—12,000 kv-a. connected capacity—is located at Galena, Illinois, and the high voltage lines extend a distance of 70 miles with six substations located along the line.

The high voltage lines traverse a mining district and the main load is chiefly induction motors. Along the high voltage lines are many small towns with lighting loads. Induction motors have a definite power factor depending on their loads, and due

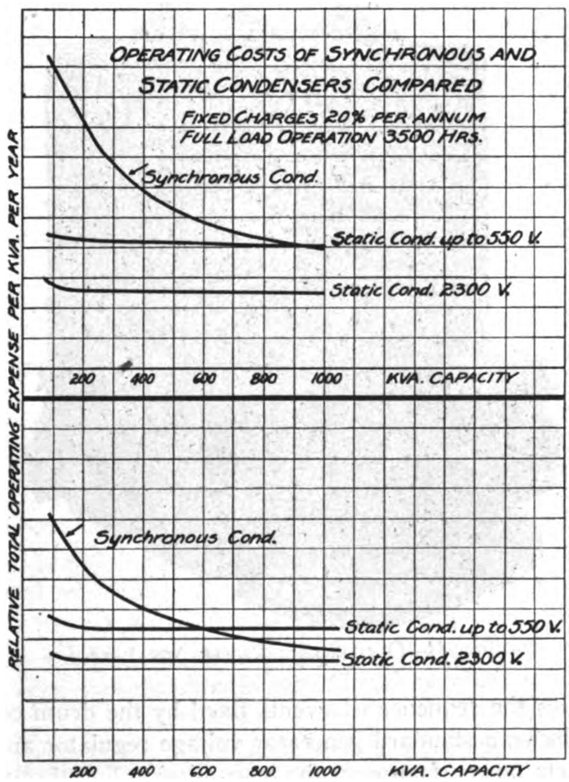

FIG. 43

to the various applications of this type of motor to mining loads, the system power factor was reduced to an average value of approximately 0.75.

The problem of excessive line drop and consequent poor line regulation, also diminishing generating capacity, demanded an immediate solution.

The usual method of improving power factor, by means of a synchronous condenser to correct line drop, poor regulation and loss of station capacity, was decided upon and in order to effect further economy it was decided to make the equipment automatic, using the same simple and rugged type of drum controller as used in the Automatic Railway Station, to function the equipment in and out of service.

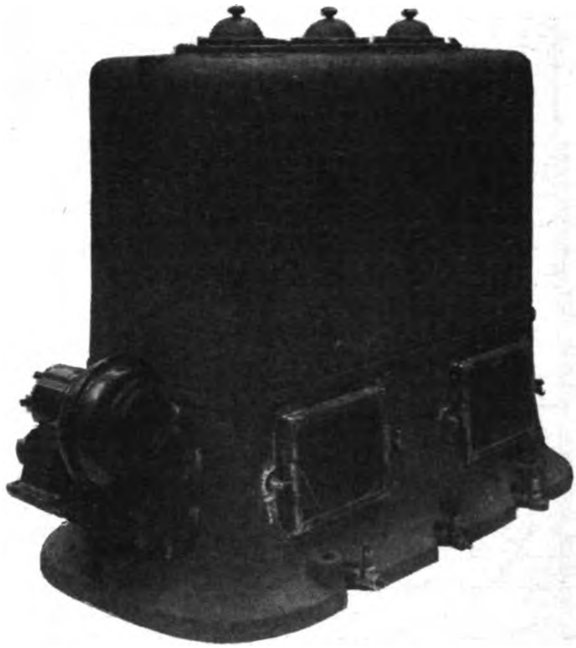

FIG. 44—OSCILLATING PHASE ADVANCER

Besides the sequence of events fixed by the drum controller and interlocks, a standard generator voltage regulator automatically corrects power factor on the transmission line through wide variations in load.

TABLE I.

Kw. Load on Station	P. F. Without Condenser	Kv-a. Load Without Condenser	Kv-a. Wattless Without Condenser	Condenser Load Kv-a.	Wattless Station Load with Condenser	P. F. of Station with Condenser	Kv-a. Station Load with Condenser	Increase in Station Capacity
7500	.825	9100	5150	3000	2150	.96	7810	1290
7000	.81	8650	5080	3000	2080	.959	7300	1350
6000	.78	7700	4820	3000	1820	.957	6270	1430
5000	.753	6650	4370	3000	1370	.963	5200	1450
4000	.725	5520	3800	3000	800	.98	4080	1440
3000	.695	4320	3100	3000	100	.999	3000	1320
2000	.670	2985	2220	2220	0	1.	2000	985

Table I gives the average daily station load and the results which are obtained when the condenser is operating under its

normal load. The maximum daily peak varies between 7000 and 7500 kw. and the minimum load is approximately 2000 kw.

The power factor given in the table is the average power factor for the kw. load.

The increase in station capacity is obtained by subtracting the kv-a. station load with condenser from kv-a. without condenser.

In observing the results obtained in automatic operation four points stand out prominently:

First: The ease and uniform accuracy with which the equipment is placed on the line.

Second: The minimum labor item entering into the cost of operation, this being periodic cleaning and inspection.

Third: The operation of the set in starting only when it is needed, variation of input being dependent upon demand for power factor improvement.

Fourth: Obtaining uniform smooth voltage charts on numerous small towns tapped from the high voltage distributing system, by careful adjusting of the voltage regulator correcting power factor at the synchronous condenser substation. It is gratifying to see the splendid voltage charts obtained from these towns contrasted with the charts previous to the installation of the condenser.

The condenser is provided with a starting induction motor and an exciter, both direct connected. The operation of the set is briefly as follows:

With a drop in voltage brought about as the result of load increase under poor power factor, a contact making voltmeter starts a motor driven drum controller which fixes the sequence of starting as follows:

1st—Synchronous condenser is started by direct connected induction motor and speed is gradually increased.

2nd—When speed approaching synchronism of set is reached, speed switch permits closing magnetizing switch, thus putting condenser on line through starting compensator as in manually operated station.

3rd—Condenser field switch closes with resistance in series to limit current input to condenser to minimum.

4th—Magnetizing and starting switches drop out, clearing

compensator from condenser, and oil circuit breaker closes, connecting machine directly to system through step-down transformers.

5th—A contactor closes and short circuits a section of condenser field resistance.

6th—The automatic voltage regulator is next switched into service. This regulator operates directly on the exciter field rheostat, which in turn increases the excitation of the condenser to a point at which the input to the condenser corrects system power factor by an amount sufficient to boost previous low voltage to a predetermined value.

Suitable protective devices guard the machine from overload and overheating.

The application of automatic condenser stations need not necessarily be confined to long transmission lines, but could be used in many large industrial plants where inexpensive housing may be provided and a careful cycle of operation worked out to insure its use only when desired.

POWER FACTORS OF VARIOUS TYPES OF APPARATUS

A. C. Welders		20 to 40%
Single-Phase Snyder Furnace	1 ton	35 to 50%
Single-Phase Snyder Furnace	3 ton	50 to 65%
Two-Phase Snyder Furnace	3 ton	80 to 85%
Two-Phase Rennerfelt Furnace	1 ton	70 to 80%
Three-Phase Moore Furnace	3 ton	80 to 90%
Three-Phase Ludlum Furnace	5 ton	75 to 80%
Three-Phase Heroult Furnace	1 ton	80 to 90%
Three-Phase Heroult Furnace	15 ton	80 to 90%
Bailey Resistor Type Furnace		95 to 100%
G. E. Tilting Type Brass Furnace, Resistor Type		95 to 100%
Annealing Furnaces		95 to 100%
Cove Baking Ovens		95 to 100%

A. C. Motor Practice

An attempt was made by the Committee to determine whether there was any generally established practice requiring large alternating current motors to be either of the slip-ring or of the synchronous type. The information so far received indicates that few companies have experienced any difficulties from the connection to their systems of large induction motors of the squirrel cage type, since few place any limit on the size of this type which may be connected.

Several companies require synchronous motors, where suited

to the load, for units of 100 horse power or more; several have schedules with advantages for high power factor loads, and all encourage the installation of synchronous motors in so far as possible.

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REPORT OF SUB-COMMITTEE ON APPARATUS FOR SPECIAL FIELDS

ELECTRIC FURNACES

The last few years have shown a great increase in the number of electric furnaces in operation throughout the country, due to their superiority over former methods of production along the following lines:

1. Better and cheaper product.
2. Adaptability.
3. Simplicity.
4. Comparatively low installation and maintenance costs.
5. Effective and simple control.
6. Safety.

Electric furnaces in most general commercial use are of the arc type, resistance type or a combination of the two, and in general are divided into two classes.

1. For smelting, stationary type, rated on 24-hour continuous output.

2. For melting and refining, tilting type, rated in holding capacity per heat.

Probably the majority of the central stations in the United States are more interested in the electric steel furnace than in any other type of electric furnace. While an immense amount of power is consumed in electric furnaces in the manufacture of ferro-alloys, such as ferro-manganese, ferro-silicon, etc., and in the production of calcium carbide and abrasives, these latter installations are pretty well confined to a few localities, whereas the electric steel furnace is found in all parts of the United States. A metallurgist and manager of a large reduction company gives the following figures as to power consumed by electric furnaces for several different products:

Products.	Kw-hr. per Ton
Steel	600 to 800
80% Ferro-Manganese	3500 to 5000
Ferro-Silicon Alloy	7000 to 9000
Tungsten or Molybdenum	8000 to 10000
Metallic Chrome (60% to 70% alloy)	10000 to 14000

In the year 1918 there was an increase in the number of electric steel furnaces of fifty-four, making the total in this coun-

try two hundred eighty-seven. When it is appreciated that there were only about twenty such furnaces in the United States on July 1, 1913, the rapid growth of the industry will be appreciated.

The majority of the steel furnaces installed at the present time range from one to six tons in capacity of metal, the installed transformer capacity for furnaces ranging from 300 to 1500 kv-a. However, several furnaces of larger size are in operation, the largest being of about twenty-five tons holding capacity, with transformer equipment of from 3500 to 4000 kv-a. capacity.

Practically all steel furnaces now being installed are of either 3-phase or 2-phase type and can consequently be operated from a 3-phase system without causing serious unbalanced load conditions. There are also a number of single-phase furnaces still being used. All electric furnaces now used in this country in the commercial production of steel are of the arc type and consequently operate at a power factor as a rule well above 80 per cent. In fact, there are several 1500-kv-a. furnaces operated on 60-cycle circuits at approximately 93 per cent power factor, whereas the power factor of a similar equipment on a 25-cycle system will occasionally go as high as 96 per cent. While a high power factor is of course desirable from the central station viewpoint, it must be remembered that to obtain a high power factor we must have a low reactance circuit, and that consequently the momentary surges which are bound to occur in any steel melting furnace, will reach a somewhat higher value in a furnace which has a very high operating power factor than in one that has a somewhat lower normal power factor. Since as a rule the greater portion of the reactance in a furnace circuit lies in the busbars and cables, the percentage reactance will vary with the arc voltage of the furnace and the kv-a. capacity of the transformer. In some furnaces which use rather high arc voltages, either during a portion or the whole of the operating cycle, an external reactance coil is connected in the circuit during that portion of the cycle for which the high voltage is used. It is seldom, except on small furnaces, that the value of the momentary current surges which occur will exceed 2½ to 3 times the normal current value. Most furnaces are now equipped with regulators which automatically maintain the power input at the desired

value, except for the momentary fluctuations which occur when a piece of metal falls against the electrode or something of that sort. These regulators have been developed to a high degree of perfection and give excellent results. (Fig. 45 shows power input to a 3-phase, 25-cycle, calcium carbide furnace equipped with automatic electrode regulator.)

Electric furnace transformers are practically always special, inasmuch as the voltages required by the furnaces are not the same as those for ordinary low voltage power service.

Ferro-alloy and calcium carbide furnaces are of the arc type, usually 3-phase, and vary anywhere from 300 to 20,000 kv-a. of

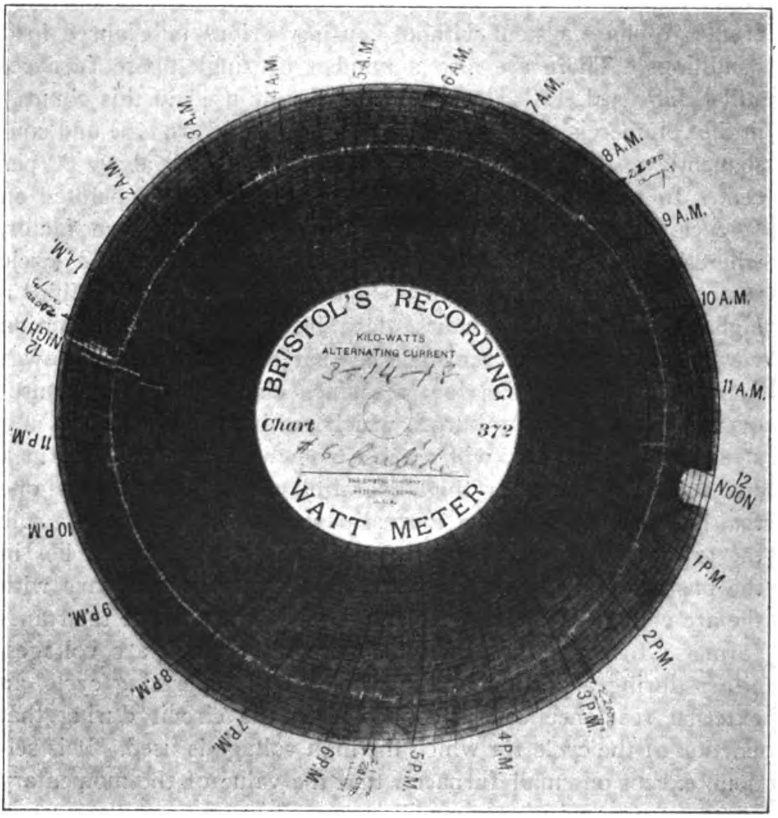

Fig. 45—Power Input to a 3-Phase, 25-Cycle Calcium Carbide Furnace Controlled by a Seede Automatic Electrode Regulator at the American Cyanamid Company, Niagara Falls, Ontario, Canada

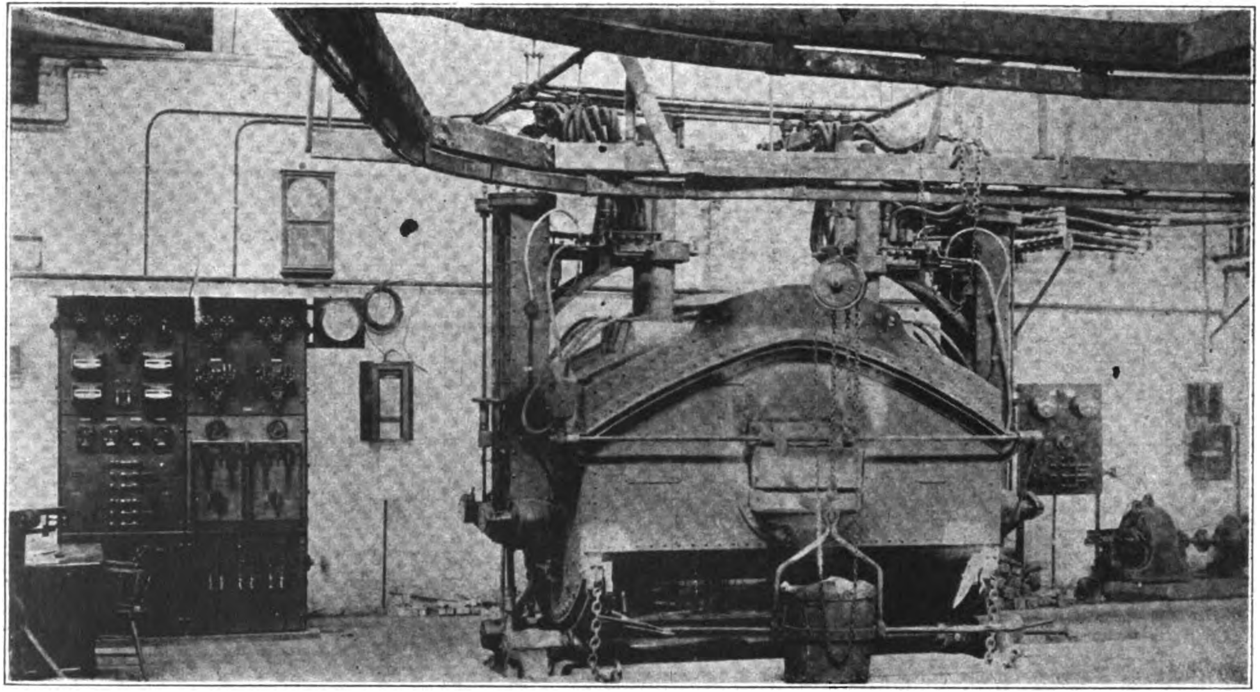

Fig. 46—1500-Lb. Brass Melting Furnace, Tilting Type

transformer capacity installed per furnace. Probably the largest single furnace installation which was put into operation in 1918 is the calcium carbide plant erected by the Government at Muscle Shoals, Ala., in connection with the nitrate development. In this plant twelve furnaces are installed, each having approximately 8000 kv-a. in transformer capacity. A ferro-manganese plant consisting of 5-5500 kv-a. transformers was also installed in Montana.

A considerable number of electric brass melting furnaces were installed during 1918, the majority of these being of small capacity, requiring about 200 to 300 kv-a. in transformer capacity. Some of these are of the arc type, some of the resistance type, some 3-phase and some single-phase. The majority of them are single-phase. Several installations of small induction type brass melting furnaces are also being made. These as a rule require approximately 80 kv-a. single-phase, at approximately 70 per cent power factor. The installation usually consists of quite a number of these small units, so that they may be distributed on the various phases of a 3-phase system, constituting practically a balanced load. Fig. 46 shows a tilting type of electric brass furnace, consuming 300 kw. and melting 1500 pounds of brass per hour. Equipments of this type have been designed for 3-phase, 2-phase and single-phase in capacities from 600 to 5000 pounds.

Bulletin 171, Bureau of Mines, "Melting Brass in Rocking Electric Furnaces," gives a résumé of brass furnace design and operation.

TABLE II.

	Electricity	Oil	Coke
Fuel Price	1¼ c. per kw-hr.	9.8 c. per gal.	$9.75 per ton
Fuel Quantity per ton	400-700 kw-hr.	50 per gal.	1200 lb.
Metal Loss—(Zn)	1.5 %	6%	3%
Zinc Value	10 cents per lb.		

Table III gives cost of melting brass (65 per cent copper and 35 per cent zinc) under average conditions in

1. An electric furnace as shown in Fig. 46.
2. An oil fired furnace.
3. A coke fired furnace.

The metal was poured at 1100 deg. cent., and the comparison is based on the figures given in Table II.

TABLE III.

COST PER TON—TWENTY-FOUR HOUR DAY

	Electricity	Oil	Coke
400 kw-hr. C 1¼	$5.00	.....	.....
50 gal. oil at $0.098 per gal	....	$4.90	.....
1200 lb. coke at $9.75 per ton	....	.....	$5.85
1½ per cent metal loss (Zn)	3.00	.....	.....
6 per cent metal loss	....	12.00	.....
3 per cent metal loss	....	.....	6.00
Crucible cost per ton	....	.....	8.00
Renewals and repairs to furnace	.50	.50	.....
Electrodes and coke	....	.....	.....
5 lb. coke and 4.5 lb. graphite	.50	.....	.....
Cost per ton (24-hr. day)	$9.00	$17.40	$19.85
Cost per ton (dirty scrap) 10-hr. day	12.75	17.40	19.85
Cost per ton (clean scrap) 10-hr. day	10.25	17.40	19.85

The induction or resistance furnace draws a steady load, free from the surges which are inherent in an arc furnace. This type of furnace has not been applied with any success to steel making in this country, although a good deal of experimental work has been carried on. However, the prospects are that in the future the induction furnace may be used extensively for steel melting, if the difficulties that have been experienced can be overcome.

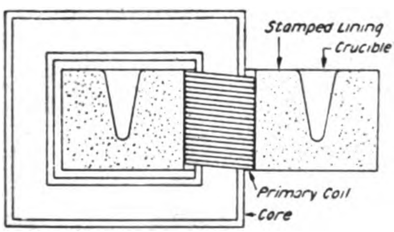

FIG. 47—VERTICAL SECTION OF AN INDUCTION FURNACE

Figs. 47, 48 and 49 show principle of operation and construction of an induction furnace, in which heat is generated by passing current through the charge of metal. A ring shaped hearth is built around core and primary windings, which, when filled with metal, forms the secondary of transformer.

The various types of furnaces developed have somewhat different characteristics, consisting principally in the location of electrodes and electrical connections. Those favoring bottom electrodes claim in general that their use prevents chilling of

FIG. 48—C

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FIG. 4

Make.
Heroult ....
Girod ....
Snyder ....
Gronwell ......
Rennerfelt ....
Nathusius .....
Greaves-Ethells.
Booth-Hall ....
Ludlum ....
Moore ....
Vom Baur .....

A report fro
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One 1-ton Heroul
Two 1-ton Renne
Three 1-ton *Sny

*Single-phase
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: STEEL

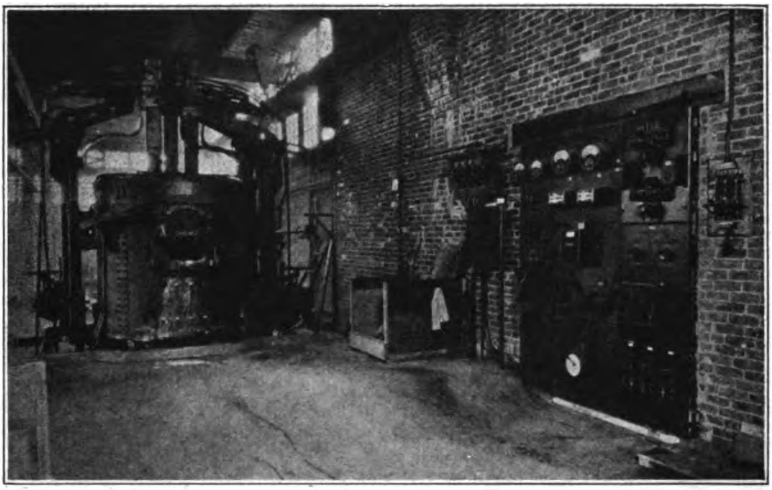


FIG. 53—ONE-TON BOOTH-HALL ELECTRIC FURNACE EQUIPPED WITH AUTOMATIC ELECTRODE REGULATOR AT NEW ENGLAND STEEL CASTINGS CO. EAST LONGMEADOW, MASS.

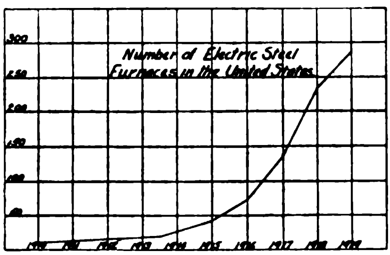


FIG. 54

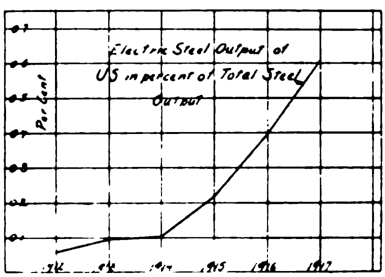


FIG. 55

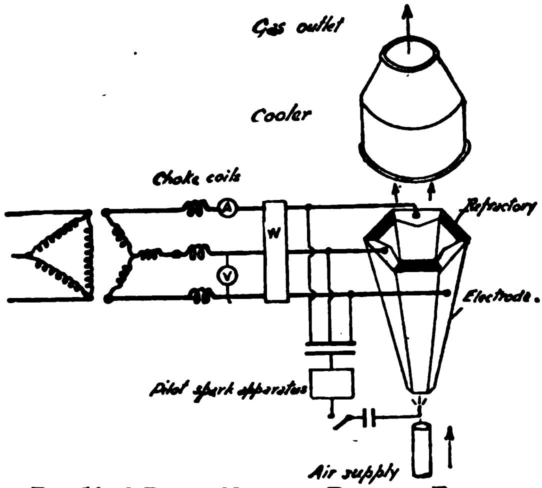


FIG. 56—3 PHASE NITROGEN FIXATION FURNACE

FIG. 57—INSIDE OF SECTION FOR ELECTRICALLY HEATED GUN FURNACE. DIAMETER, INSIDE BORE, 4 FEET

trouble is experienced due to poor voltage regulation caused by heavy current surges through furnaces operating with too low reactance values.

One company with several types of furnaces on its lines reports regarding the operation of two sizes of the same type:

2—15 ton supplied from 3000 kv-a., three-phase transformers, 11,000 volt, Primary Reactance 4.27 per cent.

1—1 ton supplied from 3-200-kv-a., single-phase transformers, 2080 volt, Primary Reactance 2.15 per cent.

"The power factor of these is good, but the reactance on the one ton outfit is so low that if it were not on its own line, service to other consumers would be greatly impaired, due to the very violent fluctuations caused by low reactance of transformers. No appreciable fluctuation is noticed on the 15-ton furnaces fed from 11,000-volt lines."

Another company reports, "We have a number of furnaces on our system and have found that, because of rapid fluctuations from overload, it is necessary to run separate circuits from the station or substation to the furnace, except when it is of very small capacity, i.e., less than 150 kw. We have also found that even with a separate circuit the larger furnaces are apt to disturb the voltage regulation of other consumers if the reactance of the furnace and transformers is not properly proportioned. We have adopted a rule that in the future all furnace installations must have a reactance such that no more than twice the full normal current will flow even with a short circuit. This has been found necessary, as the substations from which these furnaces are supplied are fed by long transmission lines."

Another company reports, "There are only two electric furnaces connected to our lines. One furnace is rated at 750 kv-a. and the other at approximately 1000 kv-a. Both furnaces are of the 3-phase type and to date we have suffered no inconvenience from having them on our lines. The furnaces are located approximately seven miles from our substation which supplies them and are fed from a line operating at 13,200 volts, 3-phase, 25 cycles."

Nitrogen Fixation Furnaces

This class of furnace differs from the smelting and refining furnace in that voltages of several thousand (5500-6600 at 25 or 60 cycles) are used at the arc. Older types were of single phase, necessitating group of three for balanced load. A new 3-phase nitrogen fixation furnace has recently been developed (diagram shown in Fig. 56) which promises good results. It is claimed that the furnace operates at very high power factor, and present sizes require up to 300 kw. of energy. Suitable reactances are used to limit current surges.

This class of furnace offers good opportunities for the sale

of off-peak power, as furnace may be started and stopped at any time without affecting the character of the product. As the process consists in the formation of nitric oxide from the combination of nitrogen and oxygen at the electric arc, there are no metals to freeze when power is suddenly discontinued. Large amounts of power are usually consumed by an air nitrate factory, the average size requiring approximately 10,000 kw.

Many heat treating furnaces have been developed for shrinking and heat treatment of guns, shafts, blocks and similar pieces. This type of furnace uses heavy resistance ribbon wound back and forth on moulded brick insulators inside the cylinder wall. Electric current is circulated through ribbon to heat pieces inserted in cylinder. (Fig. 57.) Furnaces of this type are made either vertical or horizontal.

1. Shrinking furnace designed for temperatures up to 1000 deg. fahr. Built in horizontal or vertical sections of standard size to give desired length or height. Usually hand control.
2. Heat treating furnace designed for temperatures up to 1600 deg. fahr. Generally similar in construction to shrinking furnaces, except designed for higher temperature. Usually automatically regulated.

A great many of both types of heat treating furnaces have been installed throughout the country during the past two years and the excellent power factor and load factor of a group of such furnaces make a very desirable load. Power required—from 35 to 500 kv-a. for various furnace sizes.

Electric Welding

The development of electric welding apparatus during the past few years has been very marked, particularly in its application to the shipbuilding industry where great improvements have been made in speed, economy, efficiency and convenience.

It is estimated by the Welding Committee of the U. S. Shipping Board, Emergency Fleet Corporation, that

1. A saving is effected of
   - (a) 60 per cent in riveting minor parts of a ship.
   - (b) 25 per cent in riveting the hull plates of a ship.
2. Spot welds can be made stronger than the plates joined.

3. Butt welded joints have 90 per cent of the plate strength and over 100 per cent with butt straps, whereas triple riveted joints have only 70 per cent or less.
4. As more confidence in the welded joint is demonstrated by actual experience at sea, a 20 per cent saving in steel required may be made in reducing the strength members of the ship due to the higher efficiency of the welded joints.
5. Greater speed and uniformity on the straightaway parts of ship joints will be secured by the use of automatic welding machines which partially eliminate the human element.

While the classification societies of this country have formally approved for welding only certain minor parts of a ship, several welded ships of small sizes are now under construction in England and a 275-ton cross channel welded barge has been in service since June, 1918. The general opinion is that electric welding defects are mechanical, not the fault of the process, and that the establishment of welding as a skilled trade would supply a class of operators which would quickly establish the superiority of the process over old methods.

A classification of welding may be made under two subdivisions.

1. Resistance welding.
2. Arc welding.

The greater part of the development has been along the line of the application of welding rather than the design of welding apparatus. However, many new and convenient pieces of apparatus embodying old principles have been brought out both of the Resistance and Arc type. A brief description of some of the more commonly used follows.

Resistance Welding

Portable spot welder to replace riveting machine, 27 inch reach. Capacity 31,000 amperes. Operates on 440-volt, 60-cycle circuit and requires 350 kv-a. input to primary. Also operates on 220-volt, 25-cycle circuit. Power factor 30 to 40 per cent on 60 cycles and 60 to 75 per cent on 25 cyles. Maximum mechanical pressure 25,000 pounds from 8-inch air cylinder with air pressure

100 pounds per square inch. Pressure reducing valve is provided for work requiring lower pressures. (Fig. 58.)

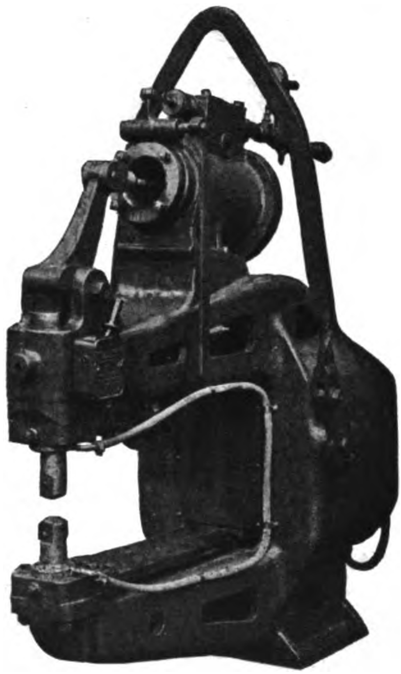


FIG. 58—ELECTRIC WELDER—27 INCH REACH
CAPABLE OF WELDING TOGETHER TWO STEEL PLATES 5/8 INCH THICK IN SPOTS 1 INCH IN DIAMETER

Small portable welder for splicing and welding iron mesh re-inforcing rods. (Fig. 59.)

Self-contained portable rivet heater of series conduction type. Rivets are placed in series, one between each pair of water cooled jaws and heated in such a manner that shank is hotter than head, resulting in a more perfect upset of rivet without marring the head. (Fig. 60.) Table IV of rivet heater capacities shows sizes in which this equipment is manufactured.

Some very large alternating current spot welding machines have been built to weld ship plates, etc., and it seems probable that heavy spot welding will in time replace a considerable portion of the present riveting operation. Large spot welders of this

TABLE IV.
RIVET HEATER CAPACITIES

Kv-a.	Number Jaws	Rivet Diameter	Rivet Length	Estimated Rivets Per Hour Max. Rate	Estimated Rivets Per Hour Min. Rate
6	2	¼— ½	¾—2	250 (¼x ½)	75 (½x1—1)
12	4	⅜— ⅝	¾—2	360 (⅜x ¾)	100 (⅝x2)
18	4	⅜— ⅝	¾—2	450 (⅜x ¾)	125 (⅝x2)
18	4	¾—1	¾—2	260 (¾x ¾)	100 (1x2)
30	3	½—1	1½—6	450 (½x ½)	100 (1x6)
30	4	¾—1¼	1—6	300 (¾x1)	125 (1¼—6)

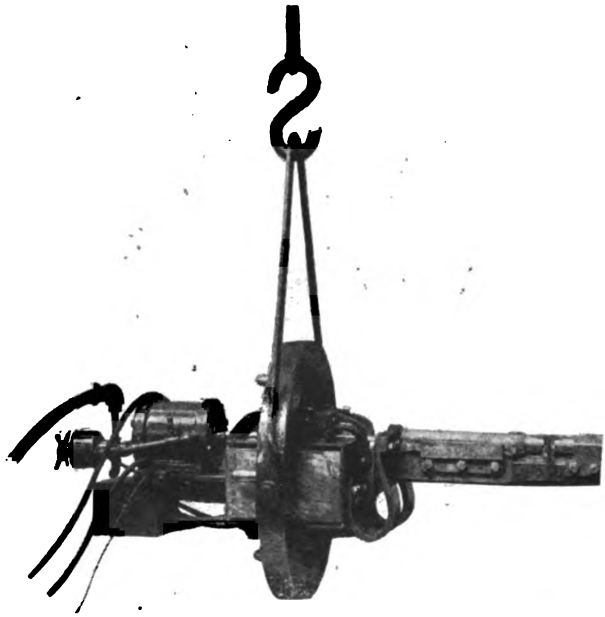


FIG. 59—PORTABLE ELECTRIC WELDER FOR SPLICING OR INTER-SECTION WELDS ON SQUARE OR ROUND RODS

type require a considerable amount of power at a low power factor, usually from 30 to 50 per cent, the amount of power required ranging from 100 to 600 kv-a. in an intermittent duty cycle of the nature of 15 seconds on and 15 seconds off. Where these large welders are used to any extent it may be found best to supply flywheel motor generator sets to provide power for them, in order to secure a good power factor, distribute load over all phases and give a larger interval of time for each weld, thus substituting gradual for sudden and large changes of power. On account of the high reactance of the welding circuit, the welding

current will remain constant as the speed of the motor generator set falls away, thus favoring the use of a flywheel.

Fig. 61 shows view of a stationary duplex spot welder with 6-foot reach. Electrodes are mounted separately with separate air cylinders to secure uniformity of weld. Two transformers mounted in frame. Polarity of electrodes on one side of plate to be welded is reverse of those on the opposite side, so that secondary current from each transformer flows through each weld. Capacity 50,000 amperes, 450 kv-a. input to primary of each transformer in series. When flywheel motor generator

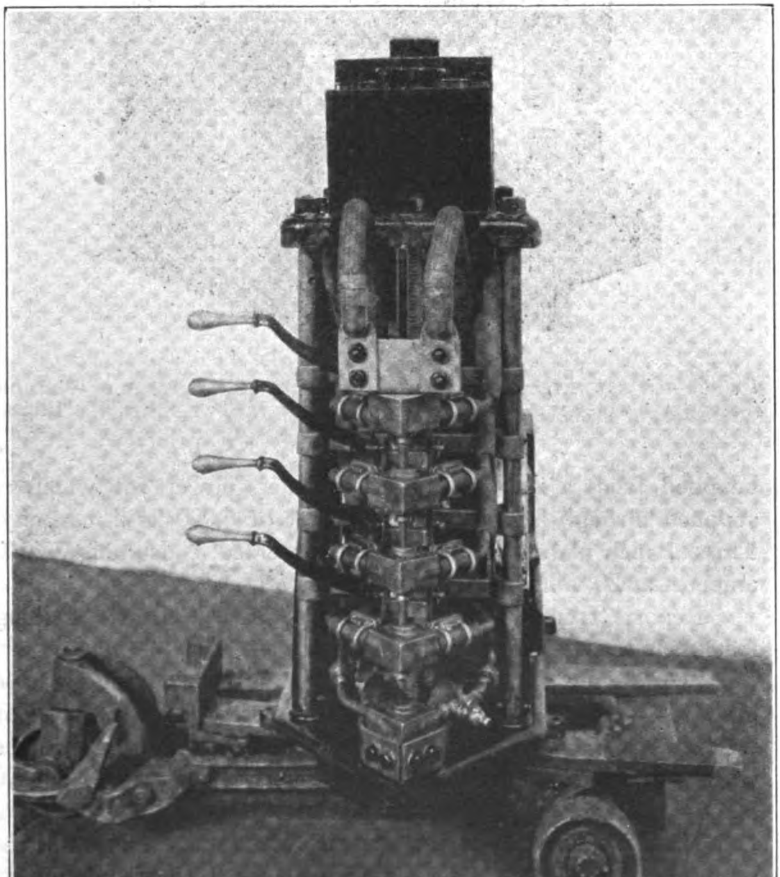


FIG. 60—ELECTRIC RIVET HEATER—FRONT VIEW

set is used, the total maximum power drawn from the circuit is approximately 100 kw.

Fig. 62 shows an experimental spot welding machine built by one of the electric manufacturing companies. This welder is

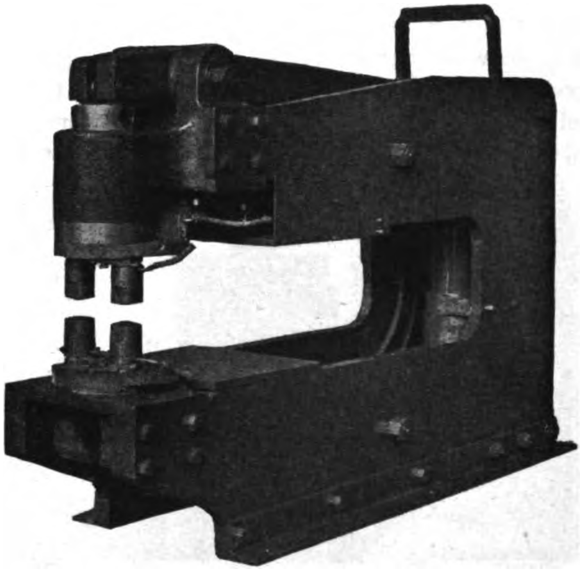


Fig. 61—Duplex Electric Welder—6 Feet Reach. Capable of Welding Together Two Steel Plates ¾ Inch Thick in Two Spots 1¼ Inches in Diameter

supplied from a 2,000 kv-a. transformer, power for which is supplied through a motor generator set of 6,000 kv-a. capacity. Three 1 inch plates were successfully welded, consuming 72,00(amperes at 20 volts and a pressure of 15 tons.

Reports from operating companies on the electric welding load include the following:

"Up to the past two or three years electric welders have given us no trouble whatsoever, but in recent years the size of welders has increased until now we have four or five on our lines which are capable of making welds for a cross section of 7 square inches. These welders require several hundred kilowatts at a comparatively low power factor, and because of the intermittent nature of the load are a serious disturbance to the regulation of the system. The revenue from them is so small that separate

lines for the welders alone are not warranted; also the fluctuations cannot be kept down by the use of reactors, as the welders require very close regulation at the welding jaws. We are at the present time considering the use of motor generator sets, perhaps with fly-wheel, in order to give more even load at a better power factor."

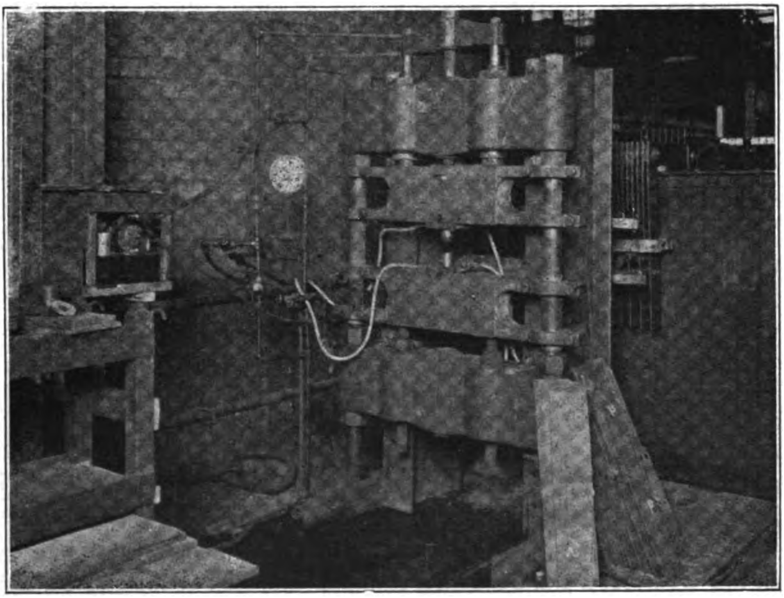


FIG. 62—MACHINE FOR EXPERIMENTAL WELDING FOR HEAVY STEEL BY ELECTRICITY, CURRENT CAPACITY 100,000 AMPERES, PRESSURE CAPACITY 36 TONS

Another report referring to the operation of large welders on the system states, "Such intermittent drafts of current are sure to result in voltage disturbances difficult to handle. It would, therefore, seem desirable to place an upper limit on the size of welder which can be supplied from the central station distribution lines directly through transformers and above that point definitely recommend the use of flywheel motor generator sets or other means of peak and phase equalization.

"It is our understanding that some difficulty has been experienced in metering these welding loads. Due to the very low power factor and intermittent nature of the load it may be desir-

able (1) to attempt specification of limits of reactance to be employed in various sizes of welders, (2) to recommend the metering of this class of load entirely on a kv-a. basis."

Welding Transformers

No new developments have been made in welding transformers except that they are produced in larger sizes. Windings are cooled by using copper pipe as primary winding with water circulating through it, and secondary terminals are water cooled where necessary. If lower secondary coil temperatures are desirable, an auxiliary coil of copper pipe may be brazed to copper bar windings.

Arc Welding

Arc welding may be divided into alternating and direct current classes. Considerable discussion has taken place over the relative merits of the two methods.

Alternating Current Arc Welding Apparatus

Some welding apparatus designed for the use of an alternating current at the arc has been produced. The usual equipment consists of a transformer of the desired current capacity having a high leakage reactance between primary and secondary. The secondary is usually designed to give the arc striking voltage of 110 on open circuit. Reactance of the transformer is sufficient to cut secondary voltage down to about 20 volts at normal welding current, which gives a power factor of approximately 18 to 20 per cent. Different secondary taps are provided to vary current values. On the usual one-man metallic electrode equipment, lowest tap gives 70 amperes at 20 volts and highest tap 200 amperes at 20 volts.

Several welding arcs within reasonable distance of each other may be operated from a constant current transformer, the current from the secondary of which flows through the primaries of all welding transformers in series. The inherent reactance of the constant current transformers is low, and the power factor of a system can be made much higher than where individual transformers are operated in multiple from a constant potential circuit.

It would appear that good and poor welds are made by all

types of electric welding apparatus and that, from the viewpoint of the quality of work produced, the type of apparatus is not so important as the skill of the operator. It is to the advantage of the central station companies to recommend to consumers on its lines, contemplating the use of welding equipment, types of welding apparatus with electrical characteristics which will preserve a satisfactory power factor and balance of the system, and which will not cause excessive voltage disturbances.

Direct Current Arc Welding Apparatus

Energy is supplied for direct current welding from constant potential, constant current or differential generators. The older type of constant potential equipment generated at from 60 to 75 volts with a series resistance provided with taps to supply various values of welding current at approximately 20 volts across the arcs. A later and more efficient development of this type generates at 35 volts and uses an automatically regulated series resistance.

The constant current generator operates with a small amount of stabilizing resistance.

The differential type consumes no energy in resistance and is highly efficient. A comparatively new equipment of this type is known as the constant energy system which embodies the principle of the ordinary balancer set. The set operates from a 125 volt D. C. line without the use of series resistance, the

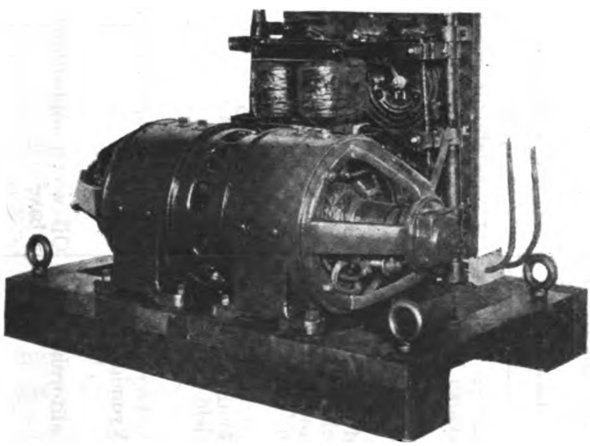


Fig. 63—Constant Energy Arc Welding Set for Metallic Welding One Man Portable Outfit, Norfolk Navy Yard

TABLE V

Location	Character of Product	Former Power Source	Electrification of Wells: Installed	Electrification of Wells: Immediate Future	Approximate Total Number of Wells
1—Eastern or Appalachian Field.	Oil generally of paraffin base. Large producers of gasoline and lubricating oils.	Gas engines, as wells are gaseous.			
2—Mid - Continental Field—Kansas, Oklahoma and Northern Texas.	Oils with both paraffin and asphaltum base.	Oil-burning boilers for steam operation.	400.	1,000 now being equipped.	70,000 shallow and 5,000 deep wells.
3—Louisiana and Southern Texas Field.	Oil principally of asphaltum base.	Oil-burning boilers for steam operation.	Just being introduced.	100 wells now being equipped.	6,000 wells drilled in 1917. Now drilling at rate of 4,000 per year.
4—Colorado and Wyoming Field.	Oil with paraffin base.	Various.	New field. Little development to date.		
5—California Field.	Oil with asphaltum base.	Oil-burning boilers.	2,000.	Several hundred a year.	8,300. Drilling 700 new wells per year, principally deep wells.

difference between the supply and arc voltage being absorbed by the motor (Figure 63).

Differential equipments are generally used for metallic welding only, one set for each welder. For carbon welding or where it is desired to operate several welders from one machine, the constant potential system is generally used to facilitate the control of current for individual welders.

Electrification of the Oil Fields

The electrification of oil wells has proceeded very rapidly within recent years due to the great economies effected. The tremendous developments in oil production are each creating a larger field for the sale of power by central station companies within whose districts the oil fields are located.

Table V gives the location of the various oil fields with some general data as to character of product and methods of operation.

As an indication of the increasing favor which electric drive is finding with oil-well operation, one of the largest producers in Oklahoma and Kansas after an extended survey of its operating conditions placed an order for 700 equipments to be added to the 30 previously installed. This is the largest single electrification so far made in this country.

During the fall the United States Fuel Administration evinced an active interest in electric operation and began a careful investigation through its Bureau of Oil Conservation at Oklahoma City to determine whether this form of drive showed material economies in oil production and fuel consumption. Unfortunately the ending of the war terminated this work, but much progress was made to indicate advantages along this line, although the data gathered were not sufficient to make final deductions.

A few instances are cited to show economies effected in the California field by the installation of electric drive, a large part of the economy being in the decrease effected in the number of interruptions of production.

22 per cent saving effected on 12 oil wells.
36 per cent saving effected on 8 oil wells.
24 per cent saving effected on 12 oil wells.

40 per cent saving effected on 107 oil wells.

63 per cent saving effected on group of wells (12 boilers discarded).

Oil wells are of two classes, deep and shallow.

An electric motor to be applicable to deep oil well service must perform two functions, pumping and pulling, the motor pumping about 98 per cent of the time and the other 2 per cent lifting and lowering tubes and tools, clearing well, baling sand, etc. These two operations demand different motor characteristics and the manufacturing companies have developed a two-speed, variable speed induction motor for this service. Previous to last year, the standard sizes were

25/10-h.p.—3-phase, 440-volt, 1200/600 r.p.m., and

30/15-h.p.—3-phase, 440-volt, 1200/600 r.p.m.

During the last year the increased requirements of some of the California deep wells resulted in the development of a heavy duty oil well motor. This new motor is a 50/20 horsepower, 3-phase, 440-volt, 900/450 rev. per min.

This type of double rated motor uses the low speed for pumping and high for pulling. Motor is equipped with double throw switch mounted on side of frame for changing the number of poles to effect change in speed. Secondary is coil wound with six collector rings connected through controller and resistors to give at either synchronous speed a 50 per cent speed reduction continuously at full load torque. Equipment also includes oil circuit breaker equipped with automatic overload coils and inverse time limit relay. Coils are double wound to protect motor on both pumping and pulling speeds, the proper coil being automatically inserted in the circuit by the speed changing switch on motor frame to prevent wrong overload coil winding being in circuit on either speed. Circuit breaker cannot be held or locked in on short circuit. Fig. 64 shows an ammeter mounted on oil circuit breaker cover which indicates actual pumping loads at all times and assists in properly counter-balancing the well. The ammeter is automatically disconnected from the circuit when pulling, etc.

A single speed induction motor is also manufactured for deep oil well service with a double throw switch on motor frame to connect windings in star for pumping and Delta to secure the

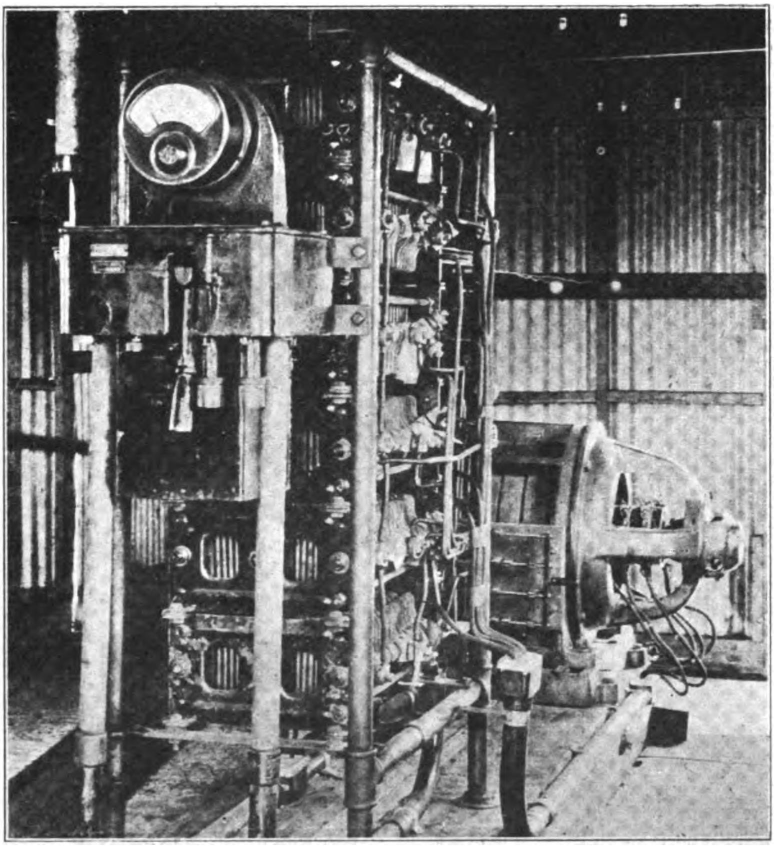


Fig. 64—Two-Speed Variable Speed Oil Well Motor Installation at Well No. 22, Porter Lease, Carter Oil Company, Midian, Kansas

additional torque required for pulling. Motor is equipped with a maximum torque switch and relay. When pumping, the motor is connected to the line through circuit breaker with overload relays, etc. When "pulling," the primary of motor is connected directly to line with maximum torque relay in series with one of the leads. If motor becomes overloaded in pulling tubing, instead of opening the circuit breaker the maximum torque relay will lift, operating the maximum torque switch which inserts the proper resistance in motor secondary to give the maximum torque. The motor may stall, but remains connected to the line, exerting its maximum torque so there is no danger of dropping the tube,

which would result in a serious loss of production. This device is also applicable to two speed motor. Figures 65, 66, 67 and 68 show motor and parts of control equipment.

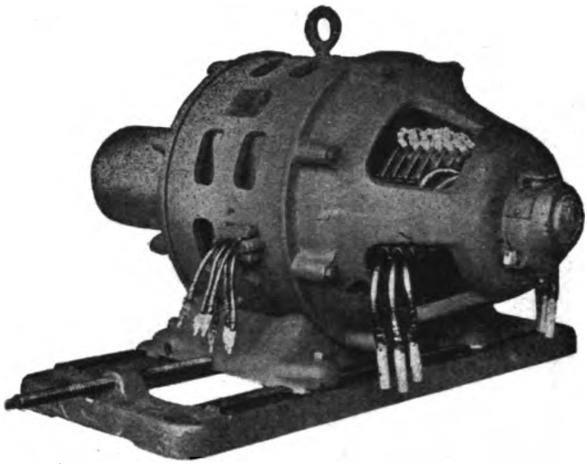


FIG. 65—TWO-SPEED, WOUND SECONDARY INDUCTION MOTOR

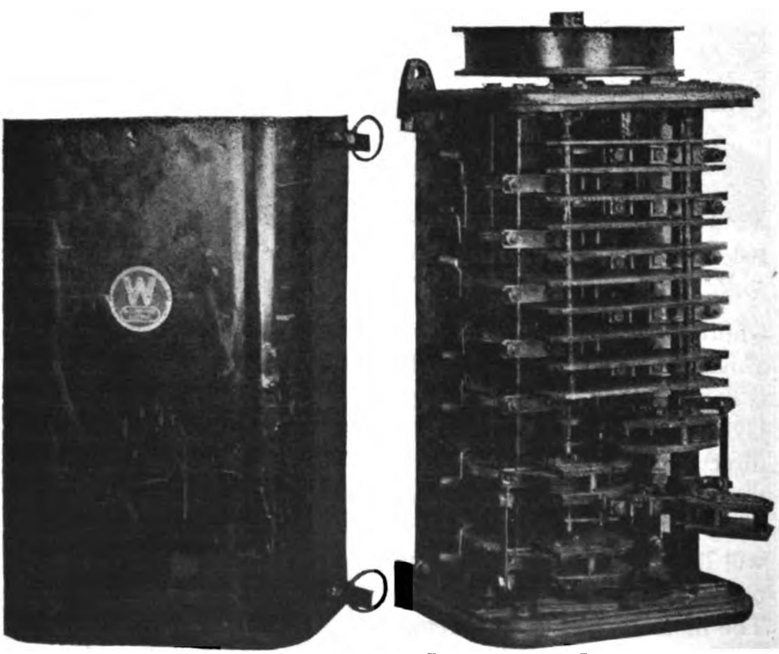


FIG. 66—CONTROLLER FOR MOTOR PRIMARY AND SECONDARY

Shallow wells may be pumped successfully individually by squirrel cage induction motors, or in groups, usually of 15 or 20 wells, by a variable speed wound secondary induction motor.

In general, oil well electrification produces a very acceptable load. Motors operate twenty-four hours per day, and while there

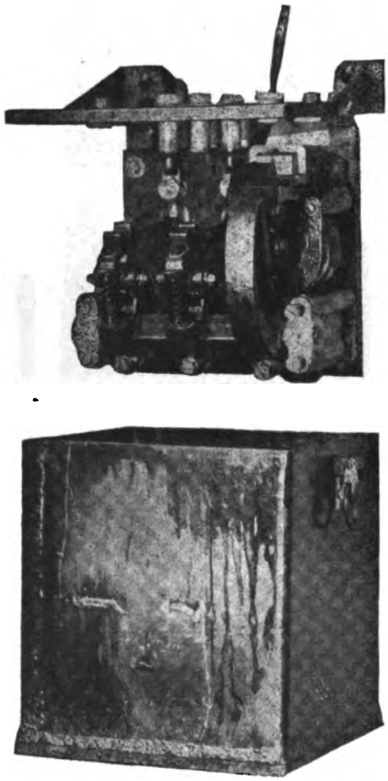


FIG. 67—MAXIMUM TORQUE SWITCH

are relatively high peaks on individual motors in their energy demand, the diversity factor produces a practically constant load on the central station system. Difficulty is sometimes caused by the low power factor of this class of load, which in some cases assumes serious proportions.

The following is a comprehensive report from one of the Pacific Coast companies supplying power to a large number of oil wells in the California field, with reference to the character-

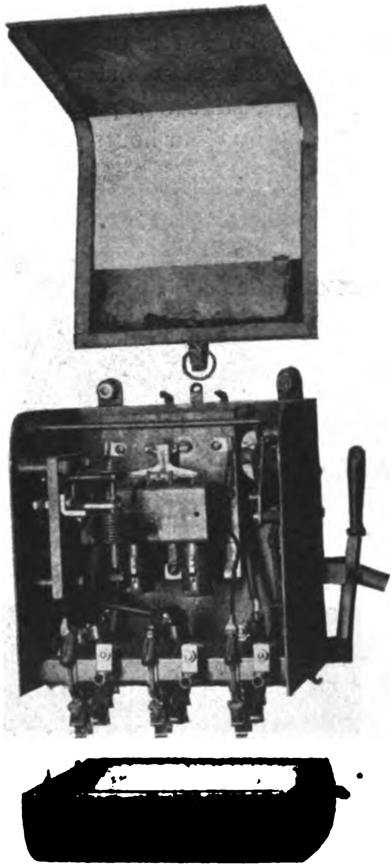


FIG. 68—COMBINED LINE SWITCH AND OIL CIRCUIT BREAKER WITH MAXIMUM TORQUE RELAY

istics of oil well motors in actual service and their effects on the central station system.

From a load factor standpoint, an oil well motor load is a very desirable one, the aim of the operators being to keep their motors pumping as continuously as possible, but from a power factor standpoint this load is not so desirable, unless proper steps are taken to improve the power factor.

The two manufacturers of oil well motors rate the performance of their 15/30-h.p. 440-volt variable speed motors as follows:

EFFICIENCY PER CENT, APPROXIMATELY—

One-half Load	Three-quarter Load	Full Load
77	80.5	81
81	83	82.5

POWER FACTOR PER CENT, APPROXIMATELY—

49	59	70
57	68	74

On actual tests of motors in service on pumping work we have found the following power factor existing:

Motor	H. P. Absorbed	Power Factor
No. 1	9.3	50%
2	8.87	58
3	10.2	50
4	10.2	50
5	8.04	38

Test No. 6 consisted of measuring the power which is metered by one meter on—

1—40-h.p. constant speed, squirrel cage motor
1—15/30-h.p. 440-volt, variable speed motor
2—10/25-h.p. 440-volt, variable speed motor

each on an individual pump. The meter showed a consumption of 62.8 horse power. The power factor of the load was 56 per cent. You will note that in this case the constant speed motor increased the power factor of the variable speed motors.

Test No. 7—We then made a test on another bank of transformers to which were connected—

5—15/30-h.p. G.E., 440-volt variable speed motors
7—10/25-h.p. G.E., 440-volt variable speed motors

All motors at time of test were being used for pumping. The horse power indicated was 122.08. The power factor was 56 per cent.

Test No. 8—Horse power absorbed 8.58. Power factor 47 per cent.

We have four substations stepping down from 70,000 volts and distributing at 11,000 volts, the bulk of the load being oil well motors. The average power factor in these stations varies from 49 per cent to 70 per cent. The total

installed capacity of the step-down transformers in these various substations is 12,000 kv-a., and the transformers are practicallly loaded to capacity in amperes.

The steps which might be taken to remedy this undesirable condition, in my opinion, are as follows:

1. The development by the manufacturers of some static condenser which could be purchased at a reasonable cost and installed at each oil well motor. So far the manufacturers have not produced such a piece of apparatus, and the price of a static condenser of this kind would probably be prohibitive.

2. The installation of a synchronous condenser which would not require constant substation attendance, operating automatically, changing its characteristics as the power factor or other conditions of the load varied, this automatic unit to be installed as near the center of the load as possible. Such a unit, I understand, is in operation at Hazel Green, Wisconsin. (See report of Sub-Committee on Power Factor Correction.)

3. The use of a constant speed squirrel cage motor to be used for pumping purposes, and a variable speed double rated motor to be used only for such other well operations as require a higher horse power. This suggestion would immediately meet with opposition from the oil well operators, owing to the loss of time in changing belts and connecting to either one of the two motors.

4. Development by the manufacturers of a new motor having better inherent characteristics. In all probability the motors as they are at present designed cannot be changed to improve the efficiency or power factor without a very large increase in the cost of the motor.

We have some 900 oil well motors on our system and their number will increase from year to year, as the oil well operators are very much in favor of electrification both from the standpoint of economy and of continuity of service. As the price of oil increases the use of electric motors will become more desirable.

NEW APPLICATIONS OF ELECTRICAL EQUIPMENT IN THE MINING FIELD DURING THE LAST TWO YEARS

Notwithstanding the fact that new developments in the mining field have been greatly curtailed during the last two years on account of the necessity for maximum production with existing equipment, a number of new applications of standard apparatus and a few applications of special apparatus have been placed in operation. These applications are of particular interest to power companies, in that they not only provide a means of increasing the load on central station systems, but in many cases improve both the load factor and power factor conditions.

The general electrification of both coal and metal mines has been particularly active during the last two years and a great many mines have completely changed over their installation from steam to electric operation. In most cases this change has caused the shut-down of isolated steam plants and the purchase of power from central stations. This is particularly true regarding the bituminous and anthracite regions. For a long time it was difficult to persuade the coal operator that he could purchase power cheaper than he could make it himself, and could effect any particular saving by electrification. This difficulty no longer exists, and the only doubts which the coal operator has are the reliability of the central station power and the cost, which has been greatly increased in some cases during the war period. In most cases the electrification of a mine consists in applying standard apparatus to replace existing steam equipment.

Some large direct current hoisting equipments have been installed, particularly in the Middle West Coal Field, as shown in Table VI.

There have also been installed a number of alternating current hoists with wound rotor inductor motors which constitute a fairly desirable load where the power system has a large capacity.

The installation of electric pumping in mines has produced a very desirable load for the central stations, in that most of the pumping can be done at night during the off-peak period, which greatly increases the load factor on the power system. A mine pump equipment of exceptional capacity is being constructed for South Africa. This consists of four units for installation underground, each comprising centrifugal pump in two sections driven

TABLE VI

No.	Size Motor	Elec. Characteristics of Motor	Power Supply	Type Drive	General
1	1150 HP	450 Volt, D.C.	Through flywheel motor generator set.	Direct connected	Regulating devices in conjunction with M.G. set equalize power demand.
2	800 HP	500 Volt, D.C. 350 R.P.M.	Through synchronous M.G. set without flywheel	Herringbone gearing	Figure 67.
1	1350 HP	500 Volt, D.C.	Through flywheel M.G. set	Direct connected	Semi-automatic, 22,000 lb. skip is started by throwing lever at shaft bottom and slowed down and stopped automatically at dump.
1	1600 HP	500 Volt, D.C. 80 R.P.M.	Through 1000 kw. flywheel M. G. set flywheel 45 tons	Direct connected	To be installed summer of 1919. Largest electrically operated hoist in Northern Iron Country.

by direct-connected 1750-h.p. 1500 rev. per min., 2000-volt slip ring induction motor, a section of pump on either side of motor. Each unit has capacity of 1200 gal. of water per minute against total head of 2600 ft. Entire equipment pumps approximately 7,000,000 gal. of water per twenty-four-hour day.

A great many mines with isolated plants are having difficulty due to the increasing distance from the power plant to the working face. This is a difficult matter to take care of with an isolated plant, but the problem is comparatively easy where central station power is purchased, due to the fact that substations can be installed at the best possible location to give good distribution to the point where power is being used. Increase in capacity and new equipment can be installed in much less time and at a very much less expense with central station power than with an isolated plant.

There have been a few installations of electric shovels and electric drag lines which until recently have been entirely steam operated. The success of these electrifications is such that there should be many installations of this type during the next

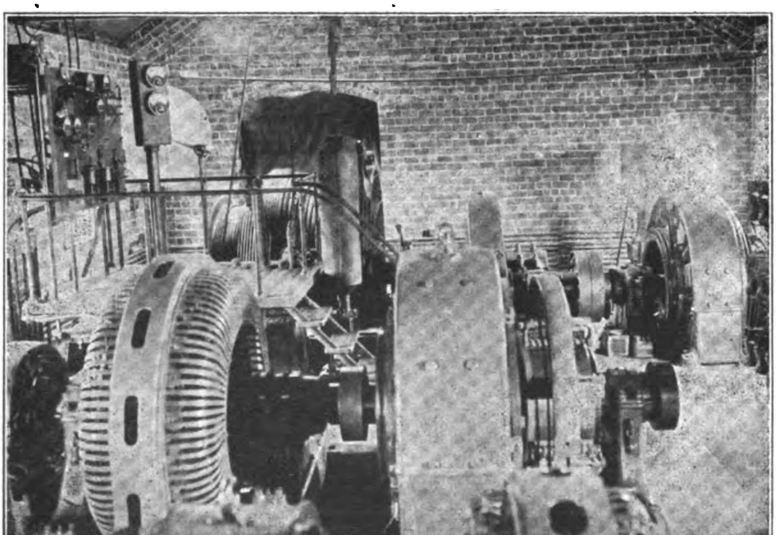


Fig. 69—Vandalia Coal Co., Mine No. 16
800 Hp. Direct Current Geared Hoist Motor Driven from Synchronous Motor Generator Set, Ward-Leonard Control

few years. It may be interesting to note that the new canal for the power system being installed by the Hydro-Electric Commission of Canada at Niagara Falls is being excavated entirely by electric shovels.

The storage battery locomotive is becoming very popular and a large number have been installed during the last two years. This locomotive is of particular interest to the central station in that in most cases power is purchased and charging is done on the central station's off-peak period. (See Fig. 69.)

A 40-ton surface haulage electric locomotive has been placed in service—the heaviest of its gauge and height constructed to date. Dimensions were restricted by low, narrow tunnel to 9 ft. in height over cab, and 6 ft. 1 in. in width; length is 31 ft.

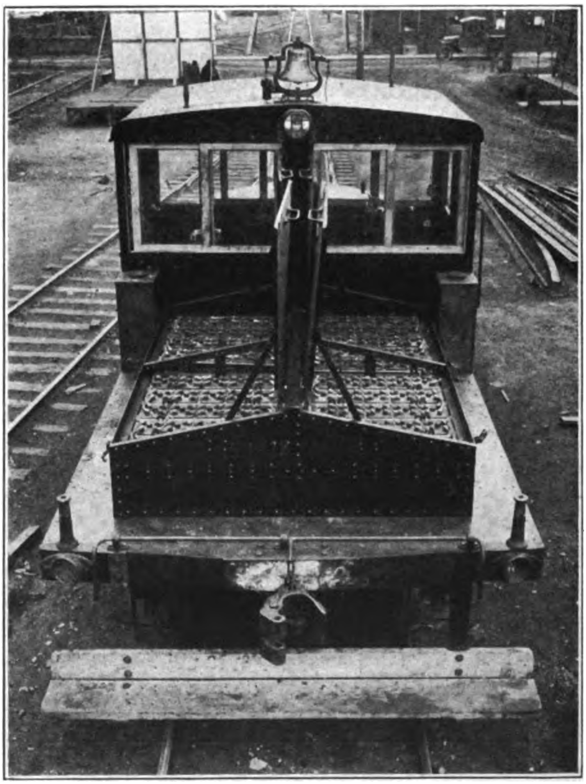


FIG. 70—STORAGE BATTERY LOCOMOTIVE

8 in. At 20 per cent tractive effort (16,000 lbs.), speed is 7 miles per hour. (Fig. 70.)

As indicated in table of recent large mine hoist installations, the practice is to use fly wheel motor generator sets to smooth out the peaks and take a more constant demand from the power lines. It is also advisable for the mining company, where power factor penalties are in effect, to consider the installation of synchronous motor generator sets, for deriving power for direct current locomotive hauling, with sufficient margin in the synchronous motor design for power factor correction.

The following is contributed by a member company:

"Interconnection of transmission lines of power companies supplying mine load principally, with companies supplying city lighting and power load, might often be advisable wherever practicable, since the peaks of the two classes of business come at different periods. The peak of the mining load occurs between the hours of 7.30 A. M. and 4.00 P. M., whereas the majority of city lighting peaks occur after 4.00 P. M."

Sub-Committee,

A S MacDowell, *Chairman*
H W Eales
L L Elden

Respectfully submitted,

R F Schuchardt, *Chairman*

H Carl Albrecht
R E Burger
H W Eales
L L Elden
H L Fullerton
S B Irelan
L M Klauber
G L Knight
A H Lawton
S J Lisberger
A S MacDowell
A A Meyer
J F Neild
G E Quinan
E A Quinn
F E Ricketts
H H Rudd
N Stahl
M O Troy
H L Wallau
W K Vanderpoel

TRANSFORMER STANDARDS

TYPES, FREQUENCIES, SIZES, VOLTAGE RATINGS, TAPS, LEAD MARKINGS, POLARITY

CONSTANT POTENTIAL TRANSFORMERS

STANDARD TYPES, FREQUENCIES, SIZES, VOLTAGE RATINGS AND TAPS

The Electrical Apparatus Committee in its 1917 Report to the Association made preliminary recommendations covering standards for various classes of transformers. In its 1918 Report, the Committee reviewed and revised these preliminary recommendations in order to make this report more complete and to bring it up to date, using as a basis suggested modifications submitted by operating and manufacturing companies. The Committee has since received further constructive criticism, also suggestions for extension of the Transformer Standards and takes this opportunity in rewriting the recommendations to include such modifications as seem warranted.

Based upon comments received, the Committee believes that the transformer standards detailed in subsequent paragraphs will be acceptable both to operating companies as meeting the usual operating requirements and to manufacturing companies as containing as much flexibility as seems generally necessary.

The Standards recommended are intended to represent the ideal toward which operating companies should work in designing new power systems and in making additions to, or gradual changes in, existing systems.

The recommendations are broad in scope and should meet the needs of a large majority of operating companies. It is appreciated, however, that there are systems whose transformer requirements would not be fulfilled by the Standards recommended and it is not the intention that such systems shall be in any way limited to them.

It is particularly important to note that the general adoption of these standards will ultimately result in material benefit to users of transformers, both Standard and Special, through re-

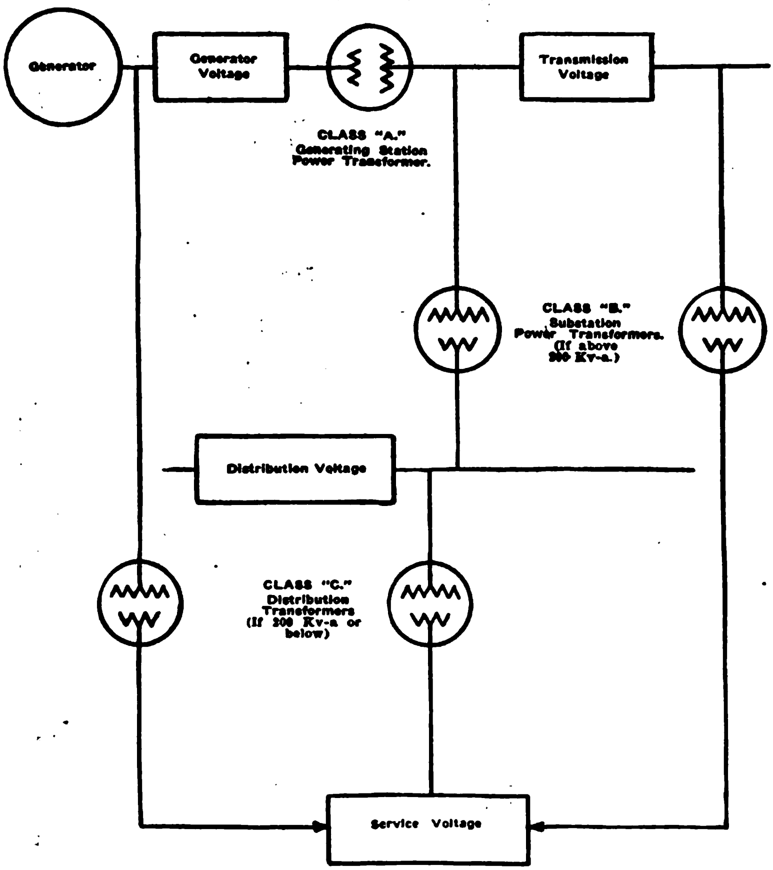
duction in prices, improvement in deliveries and elimination of many varieties of stock which had to be maintained by manufacturers under past conditions.

GENERAL GROUPS AND CLASSES

The first important point to adjust in this standardization is the general division of all transformers into groups and classes according to their accepted use and application.

All transformers are divided into two groups as follows:

DIAGRAM SHOWING THE RELATIVE LOCATION OF THE SEVERAL CLASSES OF TRANSFORMERS ON A SYSTEM



NOTE:—The above diagram is a general but typical one. It is not improbable, however, that a transformer 200 Kv-a or below in size, generally known as a distribution transformer, may be used to transform from a transmission to a distribution, or to a service voltage; also that a transformer above 200 Kv-a in size, generally known as a substation transformer, may be used to transform from a distribution to a service voltage.

FIG. 1

General Groups and Classes of Transformers

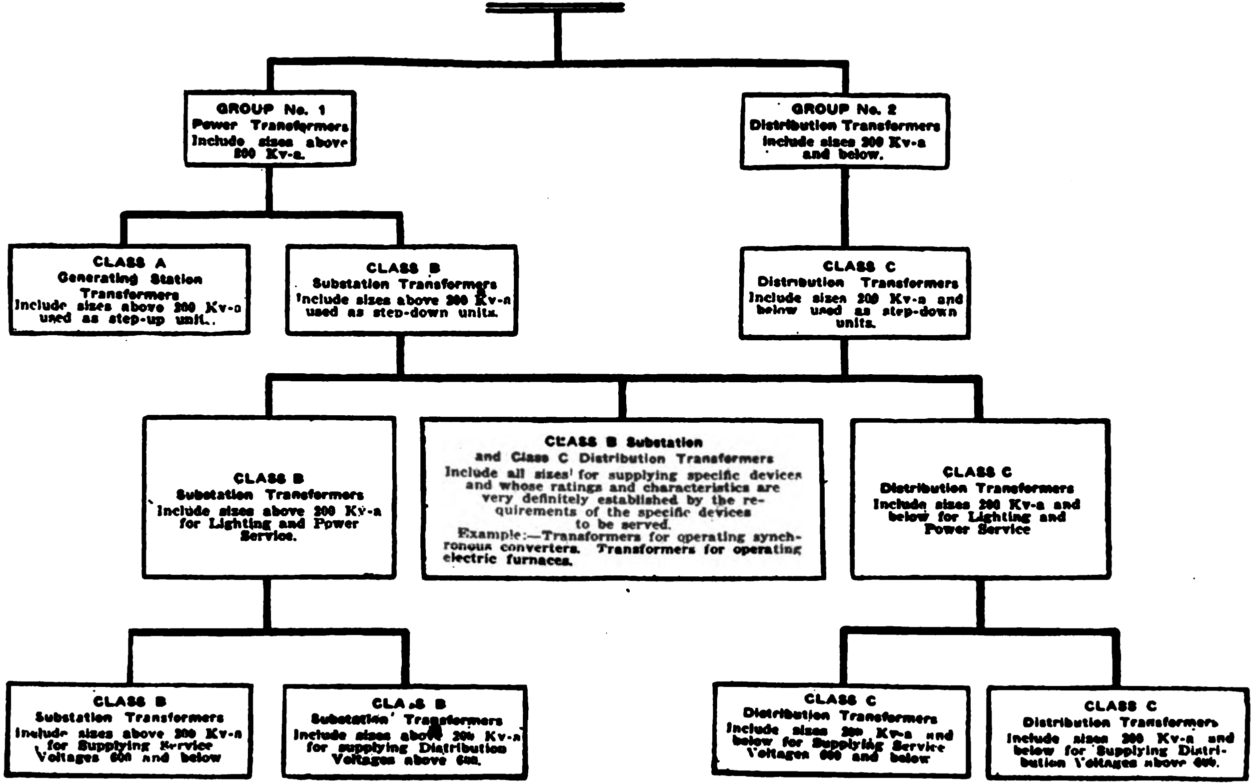


FIG. 2

Power Transformers, to include all transformers in sizes above 200 kv-a.

Distribution Transformers, to include all transformers 200 kv-a. and below.

Figure 1 illustrates the relative location of these groups on a system.

Figure 2 shows the separation of these groups into classes A, B and C and into various subdivisions.

CLASS A OR GENERATING STATION TRANSFORMERS

No definite standard voltage ratings have as yet been established for this class. For the present Generating Station Transformers should be considered as part of the generating apparatus. All requirements which would tend to complicate the design of such units and which are not essential from an operating standpoint should be eliminated.

CLASS B OR SUBSTATION TRANSFORMERS

Class B or Substation Transformers as will be noted from Fig. 2 are for convenience in standardization, segregated as follows:

Substation Transformers for Lighting and Power Service.

Substation Transformers for Special Service.

The first of these subdivisions covers transformers for supplying the usual lighting and power demands and the latter covers transformers whose ratings and characteristics are very definitely established by the requirements of the specific devices to be served. The subdivisions will be treated separately.

Substation Transformers for Lighting and Power Service:

Tables I and II, for single and three phase transformers respectively, summarize in all essential details, the standard types, frequencies, kv-a. sizes, voltage ratings and taps recommended for substation, or step-down transformers in sizes above 200 kv-a. for supplying lighting and power service.

The following comments should be noted on the standards established for this class of transformers:

1. Excepting in cases where transformer capacity is selected for operating a specific device, experience has shown that the usual practice followed in selecting transformer sizes is to con-

sider the three phase or bank capacity of the installation, rather than the capacity of the single phase units. In the standard sizes recommended, therefore, sizes of three phase units are on this basis; the sizes of the single phase units constituting the bank are one-third the bank capacity. The increments between the various sizes standardized are made fairly uniform and so small that ultimate benefit will result both to the operator and to the manufacturer if these standard sizes are maintained; particularly when it is considered that the selection of transformer capacity is usually based on a number of factors all of which are not accurately determinable, such as aggregate present connected load, power factor, load factor and estimated additional load expected to materialize within a reasonable time.

2. The double voltage rating has been standardized for substation transformers for supplying service voltages of 600 and below; the single voltage rating for substation transformers for supplying distribution voltages above 600, as the operating conditions to which these transformers are subjected seem to indicate the desirability of showing by the rating greater flexibility in design for supplying service voltages than those for supplying distribution voltages.

No definite standard transformer voltage ratings have yet been established for operation from standard system voltages above the 33,000 volt class.

The following system voltages above the 33,000 volt class have been suggested for standardization, and definite action on this suggestion will be taken as soon as comments from operators are received:

44,000, 66,000, 88,000, 110,000, 132,000, 154,000 and 220,000

The voltage rating of single phase transformers for three phase operation should indicate the external connection for which the transformers are designed. For example: 22000 if for delta connection on a 22000 volt system or 12700/22000Y if both for delta connection on a 12700 volt system and Y connection on a 22000 volt system.

The voltage rating of three phase transformers should indicate the internal connection for which the transformers are designed. For example: 22000Y if connected in Y for operation on a 22000 volt system, 22000 without further designation if con-

nected in delta for operation on a 22000 volt system or 12700/-22000Y if both for delta connection for operation on a 12700 volt system and for Y connection for operation on a 22000 volt system,

Series multiple connections on the low voltage side of substation transformers involving more than two voltages should be avoided where possible.

3. Substation Transformers may, in many cases, require taps to compensate for transformer and line drops.

As transformers with taps are more difficult to construct than those without taps on account of the difficulty in properly insulating the tap connections, it is recommended that all purchasers of transformers limit the number of taps to the lowest possible minimum, obtaining thereby transformers with safer operating characteristics. It is recommended that on single phase transformers provision be made in the high voltage winding for 10 per cent reduction in voltage by means of taps to give four equal steps of approximately 2½ per cent each; and on three phase transformers that provision be made in the high voltage winding for 10 per cent reduction in voltage by means of taps to give two equal steps of approximately 5 per cent each: further that the designs be capable of giving rated kv-a. output at any standard tap voltage without exceeding a temperature rise of 55 deg. cent., measured in accordance with the A.I.E.E. Standards. The Committee recognizes the practicability of obtaining 10 per cent variation in approximately 2½ per cent steps by the use of three taps in the high voltage winding.

4. Outdoor construction is standardized for all single and three phase self-cooled power transformers of standard ratings for lighting and power service.

Indoor construction is standardized for all single and three phase water-cooled and air blast power transformers.

This recommendation covering outdoor construction for self-cooled transformers for lighting and power service specifically excludes transformers for special service as those for operating synchronous converters, electric furnaces, etc. Such transformers are generally installed indoors and usually have very heavy low voltage currents making outdoor construction difficult to obtain and a relatively expensive feature.

CLASS C OR DISTRIBUTION TRANSFORMERS

Class C or Distribution Transformers, as will be noted from Fig. 2, are for convenience in standardization, segregated, as follows:

Distribution Transformers for Lighting and Power Service.

Distribution Transformers for Special Service.

The first of these subdivisions covers transformers for supplying the usual lighting and power demands; the latter covers transformers whose ratings and characteristics are very definitely established by the requirements of the specific devices to be served. The subdivisions will be treated separately.

Distribution Transformers for Lighting and Power Service:

Tables III and IV, for single and three phase transformers respectively, summarize in all essential details the standard types, frequencies, kv-a. sizes, voltage ratings and taps recommended for distribution transformers in sizes 200 kv-a. and below for supplying lighting and power service.

The following comments should be noted on the standards established for this class of transformers.

1. The standard sizes of three-phase transformers listed in Table IV are based on the largest present demand by operating companies. Another recognized line wherein the three-phase sizes are generally three times the standard single phase capacities is given in a footnote to the table.

The Committee will be guided by the comments of engineers of operating companies in recommending final standard sizes for 3-phase distribution transformers.

2. The double and triple voltage ratings have been standardized for distribution transformers for supplying service voltages of 600 and below; the single voltage rating for distribution transformers for supplying distribution voltages above 600, for the reason that the operating conditions to which these transformers are subjected and quantity production by manufacturers of transformers for supplying service voltages, indicate the desirability of showing by the rating greater flexibility in

design for supplying service voltages than those for supplying distribution voltages.

No definite standard transformer voltage ratings have yet been established for operation from standard system voltages above the 33,000 volt class.

The following system voltages above the 33,000 volt class have been suggested for standardization, and definite action on this suggestion will be taken as soon as comments from operators are received.

44,000, 66,000, 88,000, 110,000, 132,000, 154,000 and 220,000

The voltage rating of single phase transformers for three phase operation should indicate the external connection for which the transformers are designed. For example: 22000 if for delta connection on a 22000 volt system or 12700/22000Y if both for delta connection on a 12700 volt system and Y connection on a 22000 volt system.

The voltage rating of three phase transformers should indicate the internal connection for which the transformers are designed. For example: 22000Y if connected in Y for operation on a 22000 volt system, 22000 without further designation if connected in delta for operation on a 22000 volt system or 12700/22000Y if both for delta connection for operation on a 12700 volt system and for Y connection for operation on a 22000 volt system.

On the 2200 and 2400 volt single phase distribution transformers heretofore rated 1100/2200 and 1200/2400 volts the 1100 and 1200 volt ratings are rarely used at the present time. They are therefore omitted from the standardized ratings.

It is recommended that a triple voltage rating be adopted as standard for single phase distribution transformers of the 2300 volt class to replace the two lines heretofore manufactured, *i.e.*:

$$\text{One line} \left\{ \begin{array}{l} 2200 \text{ to } 110/220 \\ 2300 \text{ to } 115/230 \\ 2400 \text{ to } 120/240 \end{array} \right\} \begin{array}{c} \text{in place} \\ \text{of two lines} \end{array} \left\{ \begin{array}{c} 2200 \text{ to } 110/220 \\ \text{and} \\ 2400 \text{ to } 120/240 \end{array} \right\}$$

This change facilitates delivery, reduces stocks and increases interchangeability.

Series multiple connections in the low voltage winding of distribution transformers of more than one combination are par-

ticularly undesirable from the standpoint of best transformer design and construction and are confined to combinations such as 115/230 or 230/460 volts and not such as 115/230/460 volts.

Since regulation taps are recommended for standard distribution transformers of the 6600 volt class or for higher voltages, series-multiple connections on the high voltage side of such transformers are omitted because of added design complications that would result from these combined features.

Several large systems using single phase distribution transformers of the 2300 volt class and of a 9:1 ratio find it impracticable to change to a 10:1 ratio, and it is therefore recognized that the production of transformers of 9:1 ratio cannot be abandoned. In new developments, however, it is recommended that the ratio shown in the table of standards be adopted.

3. Taps on distribution transformers wound for voltages below the 6600 volt class should not be necessary in good central station practice, as potential regulators are generally used to compensate for variations in voltage.

Transformers of the 6600 volt class or for higher voltages are generally used on systems serving a wide territory and under conditions usually requiring taps to deliver proper voltage at the customer's service.

Therefore, standard single phase transformers of the 6600 volt class or for higher voltages will be provided with taps in the high voltage winding for approximately 5 and 10 per cent voltage variation and standard three phase transformers of the 6600 volt class or for higher voltages will be provided with taps in the high voltage winding for approximately 10 per cent voltage variation—exception to this rule being made only in the case of single phase transformers of the 6600 volt class for supplying service voltages of 600 and below where present established practice necessitates the standardization of the following taps for such transformers.

6300/6000/5700 based on 6600 to 110/220 or to 220/440 or to 550 volt operation,

6585/6275/5960 based on 6900 to 115/230 or to 230/460 or to 575 volt operation,

6875/6545/6220 based on 7200 to 120/240 or to 240/480 or to 600 volt operation.

It is recommended that no taps be specified in the low voltage winding of distribution transformers.

Inasmuch as taps in three phase transformers multiply complications by three as compared with single phase transformers, unusual care should be exercised in specifying the minimum number of taps on three phase transformers.

4. Outdoor construction is standardized for all single and three phase distribution transformers of standard ratings for lighting and power service.

This recommendation specifically excludes transformers for special service such as those for operating synchronous converters, electric furnaces, etc. Such transformers are generally installed indoors and usually have very heavy low voltage currents making outdoor construction difficult to obtain and a relatively expensive feature.

CLASS B OR SUBSTATION AND CLASS C OR DISTRIBUTION TRANSFORMERS FOR SPECIAL SERVICE

Under this heading have been classified transformers whose ratings and characteristics are very definitely established by the requirements of the specific devices to be served.

Although standards have been individually established by various manufacturers and a number of operating companies have certain requirements which must be fulfilled by transformers for operating synchronous converters, electric furnaces, etc., the Electrical Apparatus Committee has not yet attempted to harmonize these requirements and establish definite standards which would fulfill the majority of existing conditions.

BASIS OF PERFORMANCE GUARANTEES

The following recommendations covering performance guarantees apply to all standard transformers:

All guarantees covering characteristics and tests shall conform to the A. I. E. E. Standardization Rules.

In the case of transformers having a single voltage rating and provided with taps, the maximum rated voltage shall always be considered the normal voltage rating. In the case of transformers having a double or triple voltage rating, the rating appearing in bold type shall be considered the normal voltage

rating. Performance guarantees on such transformers shall be based on normal voltage rating and full winding—exception to this general rule being made only in the case of temperature guarantees and insulation test guarantees.

Temperature limits established by the A. I. E. E. shall not be exceeded on substation or distribution transformers for lighting and power service, irrespective of whether they are excited on full winding or, for transformers with taps, on any standard tap of 10 per cent or less range—provided that for transformers having a single voltage rating the rated low voltage is delivered at the transformer terminals and for transformers with double or triple voltage rating the voltage delivered at the transformer terminals does not exceed the maximum low voltage rating and is not lower than the minimum low voltage rating.

Insulation test guarantees shall, in the case of transformers having a single voltage rating, be based on 5 per cent above the rated voltage, and in the case of transformers having double or triple voltage ratings, be based on the maximum rated voltage.

STANDAR

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Oil Immersed
Air Blast

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Transformer
to systems w
not exceed 2

Standard System Voltages	Standard Si for Each Voltage Cl
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2300	250 to 500
4600	250 to 500
6600	250 to 500
11000	250 to 500
13200	250 to 500
22000	250 to 500
33000	250 to 500

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Standard System Voltages
2300
4600
6600
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22000
33000

NOTE.—Vol
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Standard System Voltages	Sta[illegible] Vo[illegible]
440	1-2-3
550	1-2-3
2300	1-2-3
4600	1-2-3
6600	1.5-3
11000	2.5-5-
13200	2.5-5-
22000	5-10 t
33000	10 to

NOTE.—Voltage ra[illegible] former is s[illegible] transforme[illegible]

Standard [illegible] temperatur[illegible]

NOTE.—

RULES FOR TRANSFORMER LEAD MARKINGS

(These rules do not apply to Auto Transformers.)

IN ACCORDANCE WITH THE RECOMMENDATIONS OF THE GENERAL CONFERENCE COMMITTEE ON TECHNICAL SUBJECTS—FEBRUARY, 1918. EXTENDED TO INCLUDE SUBSEQUENT MODIFICATIONS

The General Conference Committee on Technical Subjects represented the following associations:

American Institute of Electrical Engineers.
National Electric Light Association.
The Electric Power Club.
Association of Edison Illuminating Companies.

General

1. *Scope.*

These rules specify the markings of leads brought out of the case but not the markings of winding terminals inside of the case, except that these terminals shall be marked with numbers in any manner that will permit of convenient reference and that cannot be confused with the markings of the leads brought out of the case.

Note.—It is recognized that special cases will arise from time to time that these rules will not cover and that it would be very difficult to cover by any set of general rules.

2. *Markings of Leads.*

(*a*) In General. The leads shall be distinguished from one another by marking each lead with a capital letter followed by a number. The letters to be used are: *H* for high voltage leads, *X* for low voltage leads and *Y* for tertiary winding leads. The numbers to be used are 1, 2, 3, etc.

Note.—By "tertiary winding" is meant a third winding that, compared with both of the other two windings, has smaller kv-a. rating than either or, if the kv-a. rating is the same as one or both of the other two, has lower voltage.

E.g., if a transformer has three separate windings,

one for 1000 kv-a., 33000 volts; one for 600 kv-a., 550 volts; and one for 400 kv-a. 6600 volts, the 400 kv-a. winding is the tertiary winding.

Or, if a transformer has three separate windings each with a capacity of 1000 kv-a. and with voltages of 33000, 6600 and 550 respectively, the 550 volt winding is the tertiary winding.

According to this definition neither one of two similar windings arranged for series-parallel connection is to be classed as a tertiary winding.

(*b*) A neutral lead shall be marked with the proper letter followed by *O, e.g., HO, XO.*

Exception.—A lead brought out from the middle of a winding for some other use than that of neutral lead, *e.g.,* a 50 per cent starting tap, shall be marked as a tap lead.

3. *Diagrammatic Sketch of Connections.*

The manufacturer shall furnish with each transformer a complete diagrammatic sketch showing the leads and internal connections and their markings and the voltages obtainable with the various connections.

This sketch should preferably be on a metal plate attached to the transformer case.

SINGLE PHASE TRANSFORMERS

4. *Order of Numbering Leads in any Winding.*

The leads of any winding (high voltage, low voltage or tertiary) brought out of case shall be numbered 1, 2, 3, 4, 5, etc., the lowest and highest numbers marking the full winding and the intermediate numbers marking fractions of winding or taps. All numbers shall be so applied that the potential difference from any lead having a lower number toward any lead having a higher number shall have the same sign at any instant.

If a winding is divided into two or more parts for series parallel connections, and the leads of these parts are brought out of case, the above rule shall apply for the series connection with the addition that the leads of each portion ot

TRANSFORMER LEAD MARKINGS SINGLE PHASE TRANSFORMERS

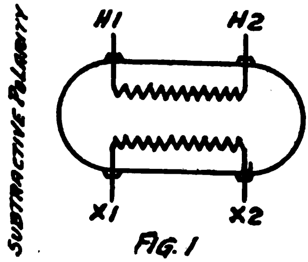


FIG. 1

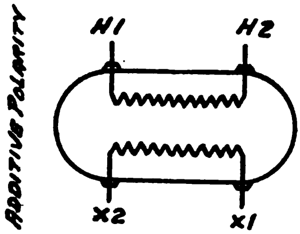


FIG. 2

SIMPLE HIGH AND LOW VOLTAGE WINDINGS WITHOUT TAPS

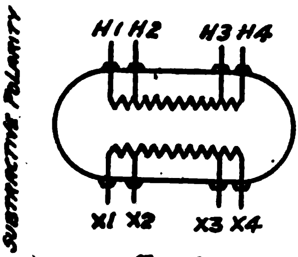


FIG. 3

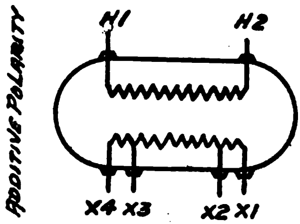
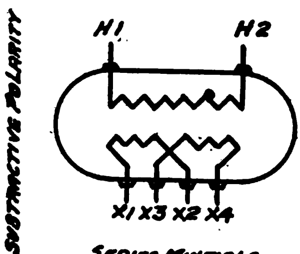


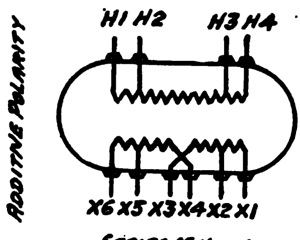
FIG. 4

SIMPLE HIGH AND LOW VOLTAGE WINDINGS WITH TAPS



SERIES MULTIPLE LOW VOLTAGE WINDING WITHOUT TAPS

FIG. 5



SERIES MULTIPLE LOW VOLTAGE WINDING WITH TAPS

FIG. 6

NOTE:—The above figures illustrate the application of the rules on lead markings to transformers having subtractive and additive polarity

winding shall be given consecutive numbers. (Figs. 5 and 6.)

5. *Relation of Order of Numbering Leads of Different Windings.*

The numbering of the high voltage and low voltage leads shall be so applied that when H_1 and X_1 are connected together and voltage applied to the transformer, the voltage between the highest numbered H lead and the highest numbered X lead shall be less than the voltage of the full high voltage winding.

The same relation shall apply between high voltage and tertiary and low voltage and tertiary winding.

6. *Polarity.*

When leads are marked in accordance with the above rules, the polarity of a transformer is

Subtractive when H_1 and X_1 are adjacent (Figs. 1, 3 and 5).

Additive when H_1 is diagonally located with respect to X_1 (Figs. 2, 4 and 6).

7. *Location of H_1 Lead.*

To simplify the work of connecting transformers in parallel it is recommended that the H_1 lead shall be brought out on the right hand side of the case, facing high voltage side of the case.

8. *Parallel Operation.*

Transformers having leads marked in accordance with these rules may be operated in parallel by connecting similarly marked leads together, provided their ratios, voltages, resistances and reactances are such as to permit parallel operation. In some cases design may be such as to permit parallel operation, although due to the difference in the number of tap leads, the leads to be connected together may not have the same number.

THREE PHASE TRANSFORMERS

9. *Marking of Full Winding Leads.*

The (3) high voltage leads and the (3) low voltage leads which connect to the full phase windings, shall be marked H_1, H_2, H_3, and X_1, X_2, X_3. The full phase winding of a tertiary winding shall be marked Y_1. Y_2, Y_3.

10. *Relation between High and Low Voltage Windings.*

(*a*) The markings shall be so applied that if the phase sequence of voltage on the high voltage side is in the time order H_1, H_2, H_3 it is in the time order of X_1, X_2, X_3 on the low voltage side and Y_1, Y_2, Y_3 for a tertiary winding.

(*b*) Angular Displacement.

In order that the markings of lead connections between phases shall indicate definite phase relations, they shall be made in accordance with one of the three-phase groups shown in Figs. 7 to 14 inclusive. The angular displacement between the high voltage and low voltage windings is the angle in each of the voltage vector diagrams (Figs. 7-14 inclusive) between the lines passing from its neutral point through H1 and X1 respectively.

Any three phase transformer having a delta Y connection may be represented by voltage vector diagram either in accordance with Fig. 11 or Fig. 13. Any three phase transformer having Y delta connection may be represented by voltage vector diagram either in accordance with Fig. 12 or Fig. 14. Since these voltage vector diagrams are equivalent, it is recommended that the terminal markings for three phase transformers having delta Y connection be always made in accordance with Fig. 11 and that the terminal markings for three phase transformers having Y delta connection be always made in accordance with Fig. 12.

11. *Tap Leads.*

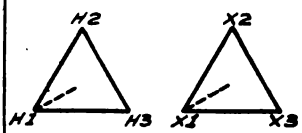
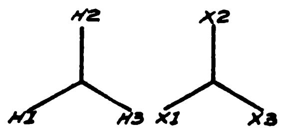
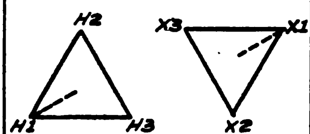
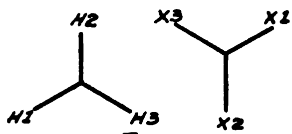
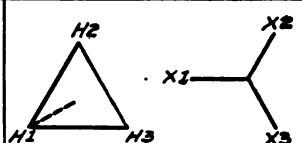
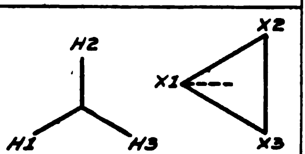
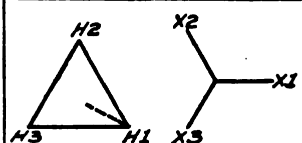
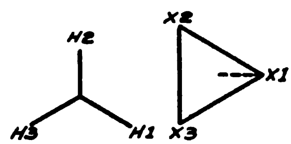
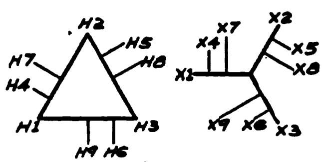
(*a*) Where tap leads are brought out of the case (neutral lead excepted) they shall be marked with the proper letter followed by the figures 4, 7, etc., for one phase, 5, 8, etc., for another phase and 6, 9, etc., for the third phase. (See Fig. 15.)

(*b*) Delta Connection. The order of numbering tap leads shall be as follows: 4, 7, etc., from lead 1 towards

lead 2; 5, 8, etc., from lead 2 towards lead 3; and 6, 9, etc., from lead 3 towards lead 1. (See Fig. 15.)

(*c*) Star Connection. The order of numbering tap leads shall be as follows: 4, 7, etc., from lead 1 towards

TRANSFORMER LEAD MARKINGS AND VOLTAGE VECTOR DIAGRAMS FOR THE USUAL THREE PHASE TRANSFORMER CONNECTIONS

<table>
<tr><td></td><td colspan="2">THREE PHASE TRANSFORMERS WITHOUT TAPS</td></tr>
<tr><td>GROUP-1
ANGULAR DISPLACEMENT
0°</td><td>
FIG. 7</td><td>
FIG. 8.</td></tr>
<tr><td>GROUP-2
ANGULAR DISPLACEMENT
180°</td><td>
FIG. 9.</td><td>
FIG. 10</td></tr>
<tr><td rowspan="2">GROUP-3
ANGULAR DISPLACEMENT
30°</td><td>
FIG. 11.</td><td>
FIG. 12.</td></tr>
<tr><td>
FIG. 13</td><td>
FIG. 14</td></tr>
<tr><td></td><td colspan="2">THREE PHASE TRANSFORMERS WITH TAPS.</td></tr>
<tr><td>GROUP-3
ANGULAR DISPLACEMENT
30°</td><td colspan="2">
FIG. 15</td></tr>
</table>

NOTE.—The above figures are included to illustrated the method of marking transformer leads that are brought out of the case and are not intended to standardize connections, Vector Diagrams or Polarity.

neutral; 5, 8, etc., from lead 2 towards neutral; and 6, 9, etc., from lead 3 towards neutral. (See Fig. 15.)

12. *Interphase Connection made Outside of Case.*
Where the interphase connections are made outside of case, the leads will be marked with the proper letter followed by the numbers 1, 4, 7, 10, etc., for one phase; 2, 5, 8, 11, etc., for the second phase; and 3, 6, 9, 12, etc., for the third phase. The markings shall be so applied that when a star connection is made by joining together the highest numbered leads of each phase, all rules here given, excepting rule (2b) apply.

13. *Parallel Operation.*
Transformers having leads marked in accordance with these rules may be operated in parallel by connecting similarly marked leads together provided their angular displacements are the same and provided also their ratios, voltages, resistances, and reactances are such as to permit parallel operation.

Note.—In some cases designs may be such as to permit parallel operation although, due to a difference in the number of tap leads, the leads to be connected together are not similarly marked.

14. *Location of H1 Lead.*
To simplify the work of connecting transformers in parallel, it is recommended that the H1 lead shall be brought out on the right hand side of the case, facing the high voltage side of the case.

THREE PHASE TO SIX PHASE TRANSFORMERS

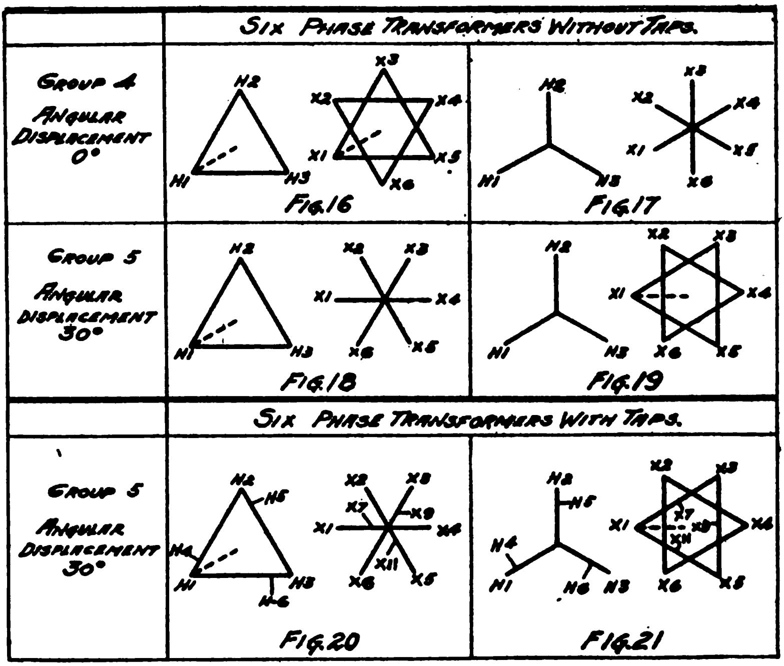
15. *Rules for Three Phase Transformers that are Applicable.*
Rules 10b and 12 shall apply to three phase to six phase transformers. Rules 9 and 11 shall apply to three phase windings but not to six phase windings.

16. *Markings of Six Phase Leads.*
The six leads which connect to the full phase windings shall be marked X1, X2, X3, X4, X5, X6. (Figs. 16-19 incl.)

17. *Relation between Three Phase and Six Phase Windings.*
(*a*) The markings shall be so applied that if the phase se-

quence of voltage on the three phase side is in the time order H1, H2, H3, it is in the time order of X1, X2, X3, X4, X5, X6 on the six phase side.

TRANSFORMER LEAD MARKINGS AND VOLTAGE VECTOR DIAGRAMS FOR THE USUAL SIX PHASE TRANSFORMER CONNECTIONS



NOTE:—The above figures are included to illustrate the method of marking transformer leads that are brought out of the case and are not intended to standardise connections, Vector Diagrams or Polarity.

(*b*) Angular Displacement.

In order that the markings of lead connections between phases shall indicate definite phase relations, they shall be made in accordance with one of the four, six phase groups shown in Figs. 16 to 19 inclusive. The angular displacement between the high voltage and low voltage windings is the angle in each of the voltage vector diagrams from its neutral through H1 and X1 respectively.

18. *Tap Leads.*

Where tap leads from low voltage windings are brought out

of the case (neutral lead excepted), they shall be marked as follows:

(*a*) Diametrical Connection tap leads shall be marked from the two ends of each phase winding towards the middle or neutral point in the following order: X7, X13, etc., from X1 towards neutral; X8, X14, etc., from X2 towards neutral; X9, X15, etc., from X3 towards neutral; X10, X16, etc., from X4 towards neutral; X11, X17, etc., from X5 towards neutral; X12, X18, etc., from X6 towards neutral. (See Fig. 20.)

A tap from the middle point of any phase winding, not intended as a neutral, shall be given a number determined by counting from X1, X2 or X3 and not from X4, X5, or X6; *e.g.*, if the only taps brought out are 50 per cent starting taps, they shall be numbered X7, X8 and X9.

(*b*) Double Delta Connection. Tap leads shall be marked in the following order: X7, X13, etc., from X1 towards X3; X8, X14, etc., from X2 towards X4; X9, X15, etc., from X3 towards X5; X10, X16, etc., from X4 towards X6; X11, X17, etc., from X5 towards X1; X12, X18, etc., from X6 towards X2. (See Fig. 21.)

Note.—For starting purposes it is generally customary to bring out only two taps from one delta and start three-phase.

STANDARD POLARITY FOR TRANSFORMERS

In the 1918 Report of the Electrical Apparatus Committee it was recommended that Subtractive Polarity be standardized for all constant potential transformers and that Additive Polarity be considered special and be used only when conditions make it impossible to use the standard polarity. The Committee solicited advice from member companies as to the desirability of putting this recommendation into effect, stating that the manufacturers stood willing to adopt the change if approved by the Association.

The replies which have been received by the Committee are so nearly unanimous in favor of standardizing Subtractive Polarity that the Electrical Apparatus Committee now feels warranted in definitely recommending that this change be approved by the Association.*

Provision will be made by the manufacturers subject to the approval of the Committee for a clear and positive identification of the polarity of all transformers and in all cases the external leads will be plainly marked in accordance with the standards already established.

The discussion on Polarity and the reasons for recommending Subtractive Polarity for all transformers are repeated from the 1918 Report of the Committee as follows:

SUBTRACTIVE AND ADDITIVE POLARITY ARE DEFINED AS FOLLOWS:

Imagine a single phase transformer having two high voltage and two low voltage external terminals, and let one high voltage terminal be connected to the adjacent low voltage terminal and let voltage be applied across the high voltage terminals. Then if the voltage applied across the unconnected high voltage and low voltage terminals is less than the voltage applied across the high voltage terminals, the polarity is Subtractive, while if it is greater than the voltage applied across the high voltage terminals, the polarity is Additive.

At the present time the voltage relation between the external terminals of most distribution transformers is such as to result in additive polarity, while the voltage relation between the external terminals of power transformers would give subtractive polarity in some instances and additive polarity in others.

As to the desirability of accepting the recommendations for the standardization of subtractive polarity for all classes of transformers the following comments are submitted:

1. It is fundamentally correct in principle.†

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* When the above recommendations relating to Polarity were presented at the Convention they were referred back to the Subcommittee for further consideration.

† For detailed discussion of Polarity see Article on Polarity of Transformers by Mr. W. M. Dann in the *Electric Journal* for July, 1916.

(*a*) Under normal operating conditions the maximum voltage stress between adjacent high voltage and low voltage external terminals is: for subtractive polarity one-half the difference between the voltages of the two windings and for additive polarity one-half the sum of the voltages of the two windings.

(*b*) Under abnormal operating conditions when a high voltage and a low voltage line may simultaneously become grounded the maximum voltage stress between adjacent high voltage and low voltage external terminals is: for subtractive polarity the difference of the voltages of the high and low voltage windings and for additive polarity the sum of the voltages of the two windings.

This advantage of subtractive polarity, although negligible in transformers for moderate or low voltages, becomes sufficient in high voltage transformers, particularly those having a relatively small ratio of transformation to make its standardization logical.

Assume a transformer having a high voltage rating of 150,000 and a low voltage rating of 100,000 volts. Under condition (*a*) the stress between adjacent high and low voltage external terminals is for subtractive polarity 25,000 volts and for additive polarity 125,000 volts. Under conditions (*b*) the stress between adjacent high and low voltage terminals is for subtractive polarity 50,000 volts and for additive polarity 250,000 volts.

2. It establishes a uniform practice.

The present practice is very inconvenient and confusing from an operating standpoint, as two transformers of the same rating but purchased from different manufacturers may have different polarity, thereby making it necessary to phase out each transformer carefully in order to make certain that it is properly connected in circuit.

3. It practically eliminates any chance of connecting the transformer to a circuit with reversed polarity.

If all transformers have the same polarity there is evidently small chance of reversed connection. If some transformers have one polarity and others another, care must be taken

at all times to make sure that each transformer is connected properly to its circuit. A connection giving the wrong polarity may cause a violent short circuit with possible disastrous results.

Respectfully submitted,

ELECTRICAL APPARATUS COMMITTEE

R F SCHUCHARDT, Chairman
*H CARL ALBRECHT
R E BURGER
*H W EALES
*L L ELDEN
H L FULLERTON
S B IRELAN
L M KLAUBER
†G L KNIGHT
*A H LAWTON
*S J LISBERGER
A S MACDOWELL
J F NIELD
G E QUINAN
E A QUINN
F E RICKETTS
*H H RUDD
*NICHOLAS STAHL
R H TAPSCOTT
*M O TROY
*H L WALLAU
W K VANDERPOEL

The Committee desires to acknowledge its indebtedness to many engineers of member companies for their helpful constructive criticism during the preparation of these Standards.

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* Member of Transformer Subcommittee.
† Chairman of Transformer Subcommittee.

THE CHAIRMAN: As usual, we will take this up section by section, and I will ask the chairman of each of the various sub-committees to open the discussion by a statement of what is in his sub-committee report. As the paper was not distributed in advance, we will ask the chairmen of the sub-committees to discuss the subjects in more or less detail, the amount of detail depending on the time that is left to us.

I will ask Mr. H. C. Albrecht to open the discussion on the Transformer Section

H. C. ALBRECHT, Philadelphia: In the absence of Chairman Knight of this Sub-Committee, I have been asked to outline this year's work.

The Standards which were adopted last year and widely distributed in pamphlet form have been revised and brought up-to-date with the help and constructive criticism of engineers of member companies. The Standards have been extended to cover 3-phase transformers, and the sizes of both single-phase and 3-phase transformers, previously standardized, have been extended up to and including 10,000 kv-a. single-phase, 30,000 kv-a. 3-phase. The Committee recommends the extension of standard transformer voltage ratings above 33,000 volts and suggests voltages up to and including 220,000 volts.

The 1918 report contained a recommendation that subtractive polarity be standard for all constant potential transformers. This year's committee requested a definite statement on this question from a large number of operating engineers and replies show an almost unanimous opinion in favor of the change. The Committee, therefore, definitely recommends the standardization of subtractive polarity. If there are any objections thereto it is trusted that the discussion this afternoon will bring them out.

The Transformer Standardization Booklet has been reprinted with the revisions, and copies are now available for general distribution.

THE CHAIRMAN: I would like to say a word with respect to cooperation between the various manufacturers and the various organizations engaged on this work—it has been splendid. The Power Club, which has been working on this problem for

some years, the Institute people, the N.E.L.A. and the various manufacturers have cooperated in an excellent spirit, and it appears now that we are reaching the point where all the manufacturers will say, "Here is a transformer which is practically the same as you can buy anywhere else, a standard throughout the United States"—which is an excellent condition to approach.

This question of Transformers is now open for general discussion.

H. B. GEAR, Chicago: We all agree that standardization of polarities is a thing much to be desired. We are put to great inconvenience when receiving transformers coming from different manufacturers, with different polarities. In considering this question of polarities, some of us have felt that in view of the additive polarity of the existing types of distribution transformer, it is going too far to attempt to standardize subtractive polarity for all transformers. There are possibly one million live transformers in service with additive polarity at the present time. The replacement of one of these units with a transformer of subtractive polarity necessitates crossing over of the leads, and rearrangements of taps to which thousands of linemen must be educated.

I can understand why subtractive polarity is desirable for station units from the manufacturing and operating standpoints; but there is little advantage for distribution transformers which are used chiefly at the lower voltages. Therefore, it seems to me that the arguments in favor of standardizing subtractive polarity for the distribution transformers do not carry great force. Only a few manufacturers have attempted to make transformers with subtractive polarities, and it would be easier to have them brought into line, for additive polarity, than to change the established practice of the whole country.

I might say in explanation of the reason why little protest has been heard on this question that the distribution men as a whole do not realize what would be done in the adoption of this report. We did not realize it in Chicago until it was brought to us a few weeks ago for approval. I would suggest that this part of the report be referred back to be taken up by a Joint

Sub-Committee of the Committee on Electrical Apparatus and the Overhead Lines Committee.

W. T. MORRISON, New York: I agree with Mr. Gear entirely, that with a large number of distribution transformers on a line it would seem undesirable to change the polarity of these transformers. It would be easy to leave the station transformers in one division, and all outside stations in another division. And it would seem to be a great pity to try to standardize something where you are changing so large an amount, to meet something which is of small quantity. The great bulk of these are additive, and it would seem that the best thing is to leave them as they are, and change the transformers of only a few manufacturers who would have to change their practice.

MR. ALBRECHT: While the Committee is ready to admit that the adoption of subtractive polarity for distribution transformers gives practically no advantages except in the line of standardization, in its judgment it is worth while to make the change to obtain that result. The tendency of the times is distinctly towards standardization in all lines. It is admitted by everyone that subtractive polarity is fundamentally correct in principle, and that there is a decided advantage in its application to high voltage transformers, particularly those having a relatively small ratio of transformation. While perhaps 90 per cent of distribution transformers are now wound with additive polarity, there would be little chance for confusion if the change were made, except where transformers are banked for 3-phase or parallel operation. It is also a question of whether the anticipation of trouble in these applications is not exaggerated.

I would like to question Mr. Gear's statement that there is a clear line of distinction between distribution transformers and power transformers. The Standardization provides that all transformers under 200 kv-a. are in the distribution class, and all those over 200 kv-a. are classed as power transformers. Power transformers are used not only for station purposes, but also in many instances on distribution circuits. The suggestion, therefore, that subtractive polarity be standard for power transformers and additive polarity for distribution transformers, would not seem to be a logical one.

I cannot say just how the proposal to standardize polarity arose, but I do not feel that the manufacturers have anything at all to gain, although they are entirely willing to make the change if the purchaser so desires. It would, therefore, seem that the only gain in the adoption of polarity for distribution transformers would be in the direction of standardization.

THE CHAIRMAN: The most practical benefit is that if all the distributed transformers came out with the same polarity the linemen would not have to be familiar with so many different ones. I think that is a question to be referred back to the joint committee, as Mr. Gear suggests.

MR. GEAR: At least 25 per cent of our distribution transformers are in three-phase installations where polarity is a factor.

THE CHAIRMAN: We will proceed now to the next division, Substation Practice, and I will ask Mr. A. A. Meyer, of the Detroit Edison Company, to make a brief statement.

MR. MEYER: In the absence of Mr. Eales, Chairman of the Sub-Committee on Substations, I will attempt to abstract briefly the report of his Committee.

The Committee has investigated several types of substations, giving particular attention to the special types of indoor stations and also the most striking features of the outdoor types.

The small industrial consumers' substations showed many similarities because this type can be constructed easily from master drawings, whereas the larger consumers' stations differed widely because they needed special consideration for each particular case. In all cases the design of the station and its equipment were either dictated or approved by the central station. The committee has endeavored to obtain cost data but is not ready to present any comparable figures.

The use of automatic and semi-automatic stations was found to be quite extensive and of particular interest. Thirty-seven automatic railway stations were in operation varying in size from 300 up to 1,000 kw. One company reported having five semi-automatic or remote control stations in operation on its Edison direct current network, each of 500 kw. capacity. These functioned to take care of low pressure valleys in scattered resi-

dential lighting districts during the peak load period and also concentrated loads such as hotels, large business houses, etc., in the downtown section.

A rather new automatic feature, incorporated by some operating companies in their ordinary alternating substations, is the automatic reclosing oil circuit breaker on the outgoing distribution lines. It is intended to re-establish service quickly on a circuit which has tripped owing to a temporary fault on the line.

There are many other items of interest which must be omitted in this limited abstract, but which can be learned by a careful reading of the complete report.

THE CHAIRMAN: The question is now open for general discussion—Substation Practice. There are still two or three chairs up here at the front, if there is anybody now standing who wishes to take one.

J. C. MARTIN, Allentown, Pa.: In the matter of outdoor substation design, during the last few months I have encountered difficulty in increasing the size of substations which were originally put in from a manufacturer's standard design. The difficulty is, that many of these manufacturers' standards are so designed that it is impossible to increase the size of the substation without tearing out the whole structure and putting in an entirely new one. It would seem that the committee could well give attention to this matter by asking manufacturers to design substation structures in such a manner that they can be readily increased in capacity without complete reconstruction.

It should be possible to design such structures so that increases can be made easily without material change in anything but the apparatus. I know of one instance in which a substation as originally installed was adequate for the situation at the time, but when an increase in capacity was needed. it was found necessary to reconstruct the whole station, and spend more money than would have been necessary had the station been properly constructed originally. It would seem that manufacturers could well give considerable attention to this matter.

THE CHAIRMAN: That is a very important question, and it has to do with the lack of imagination on the part of the engi-

neer as to the future growth of business. We find in one case we haven't enough land for expanding the plant, and the cost of the land now is half a dozen times more than we could have bought it for when the original purchase was made. It is wholly possible to design a structure without the continual expenditure of too much money to provide for future growth.

H. L. WALLAU, Cleveland, Ohio.: I would like to call attention to an article in the Electrical World of last year, describing a certain type of central station, which might be of value in considering this question of future growth.

A. E. SILVER, New York: With switchboard apparatus particularly in mind, I would like to emphasize a general principle, that of high load factor, in its application to the use of apparatus, which I believe deserves increased attention. We are now faced by a new order of conditions involving greatly increased construction costs, which means that increased care and forethought must be given to obtaining greater economy in construction designs. I believe there is opportunity for considerable gain through improving the load factor of various items of apparatus of lesser importance. For some time it has been customary to give much thought to realizing high load factors on major apparatus, such as turbo-generators. By greater effort to extend this practice to apparatus of lesser importance, it is believed frequent opportunities will be found where avoidance of duplication can be justified and material economies effected.

As an example, consider a substation for perhaps a moderate-sized city where a complete double bus arrangement would be the prevailing practice. I believe that an analysis of the reasons for providing complete duplicate switching arrangement will very often show the prime reason to be the meeting of emergencies resulting from apparatus troubles, and furthermore, that an analysis will show that a decided majority of these troubles follow from lack of proper inspection and maintenance of apparatus. Given then, suitably increased inspection and maintenance care, the duplication of such apparatus may often be omitted. Improved load factor on the switching apparatus of such a substation might be realized by a lay-out comprising one completely equipped high-class bus and some suitable means, such

as a comparatively cheap and simple inspection or maintenance bus, for cutting out any oil circuit breaker or other item of essential equipment for periodic inspection and adjustment.

This is merely to bring out my point that in these days of high costs one way to economize is to insure that every piece of essential apparatus works as nearly all the time as practicable.

R. J. WENSLEY, East Pittsburgh, Pa.: There has been one application of the automatic substation for Edison three-wire service not mentioned in the report and that is for use in large hotels or office buildings or where there is a great concentration of three-wire load. In such buildings it is possible to run fairly small d. c. copper from the street mains, thereby reducing the investment, and to put in automatic substations to take care of the load in these buildings during the day and evening, automatically cutting off the substation during the night. The cost of the automatic converter equipment is less than the heavy investment laid in the streets in the form of copper. We believe the reliability of service to be practically the same.

N. E. FUNK, Philadelphia: The people operating the Paoli Branch of the Pennsylvania Railroad, are very much dissatisfied with the alternating current operated switches and are making arrangements to change them to direct current control. Therefore, I do not feel that this particular installation is an example of satisfactory alternating current control.

One of the greatest troubles with alternating current controlled switches is that the failure of the main power supply causes the loss of the control system, and necessarily this means inconvenience and delay in restoring service. This may be avoided to some extent by a separate alternating current supply which is usually inconvenient and expensive.

The installation of a small motor generator operating continuously and a storage battery to supply service in case the main power supply, and in consequence the motor generator, fails, gives much more satisfactory control service.

N. L. POLLARD, Newark, N. J.: I should like to ask whether any of the member companies have had any trouble with water

getting into their outdoor type oil circuit-breakers. We have had several cases where moisture inside the oil circuit-breaker tank formed ice, which later caused a failure of the switch. We think that the moisture in the switch was due to condensation. I have not had time to read the report, so I do not know whether other companies are having troubles of a similar nature.

THE CHAIRMAN: Mr. Silver, can you answer that?

MR. SILVER: As far as the experience of our company is concerned, I recall only a few instances among early installations. These troubles were easily overcome in succeeding installations.

THE CHAIRMAN: The company with which Mr. Silver is connected operates a very large number of outdoor switches in the United States.

The next item is Switchboards, and I will ask Mr. Lawton to make a statement on that.

(Mr. Lawton abstracted pages 21 to 28 of the Report of the Sub-committee on Switchboards.)

A. S. LOIZEAUX, Baltimore: The subject of repeated operation of oil circuit breakers in a short interval of time brings up the question of the removal of oil fumes from the switch-pot. A recent switch breakdown in Baltimore was caused apparently by the explosion of oil fumes above the oil. The switch operated under short circuit, opening successfully. After a short interval the switch was closed and again opened automatically. An explosion occurred, blowing the switch-pots off and breaking the bolts which fastened the pots to the frame of the switch. The current flowing was well within the capacity of the switch, and examination showed almost to a certainty that an explosion of oil fumes did the damage. Certain manufacturers provide a check valve of small diameter on the top of the oil tank, but this does not provide for free circulation of air. In restoring the switch to service after breakdown, as mentioned above, it was provided with two large check valves, one at the oil surface and the other at the top of the tank. These check valves are normally open, but close during operation of the switch due to the pressure generated within. When open the check valves allow

free circulation so that any difference of gravity between oil fumes and air will cause the fumes to flow out and fresh air to take their place.

It seems that unless definite means are taken to eliminate oil fumes we may expect to have explosions under certain conditions and the switches can hardly be built to withstand such explosions. The manufacturers should determine on and install some adequate method to remove oil fumes.

H. L. SMITH: The report of this Committee is most comprehensive and opportune.

A section on oil circuit breakers has been inaugurated in the Power Club and will be ready to cooperate with the N.E.L.A. and the A.I.E.E. in the attempt to solve the problems connected with this class of apparatus

In the report stress is laid on the duty cycle as now adopted for interrupting capacity rating. The duty cycle is simply a bench-mark, as it was necessary to adopt some basis for ratings.

A great deal of argument was brought out before the present duty cycle was adopted, but this is only one basis. If your Committee through the cooperation of the member companies can suggest the proper basis, the manufacturers, I am sure, will cooperate and endeavor to relate these ratings either by curves or some other more practical method, so that the data can be given to them for any kind of application.

One other word about application and rating. In the paper which is carefully prepared, there is a tendency to confuse "application" with "rating." I merely call attention to this as a word of caution, and do not wish to enter into argument about it here.

The collection of the data proposed in the paper, both on successful or unsuccessful operation of breakers, accurate and complete for any given case, will naturally be of the greatest importance to the manufacturers in assisting them to determine—as well as the member companies to decide—whether a particular form of breaker is best adapted to a particular application, or whether its rating is a proper one.

THE CHAIRMAN: Any more discussion on this question?

J. B. MACNEILL, Pittsburgh, Pa.: If the duty cycles for oil

circuit breaker operation are made more stringent, then breakers must be more conservatively applied than is now the general practice; that is, if an oil breaker must open three times on short circuits, say 10 seconds apart, it must be a breaker of greater ability than if it opened only once or if it opened twice with a 2 minute interval. There are no limits, however, to the application of the fundamentals of oil breaker design, and this greater ability can be secured by simply making them bigger and better along the lines of design now used.

With respect to the progressive heating of air circuit breaker contacts, we have been recommending for certain installations that oil breakers be used where hitherto carbon breakers have been used. For the protection of station auxiliaries, etc., where the load is continuous for several weeks perhaps, the oil breaker gives much better satisfaction since the contacts do not oxidize, and there is, therefore, no progressive heating.

With respect to the novel combination of oil circuit breaker and air disconnecting switch described, the purpose of this device is to insert immediately an air break in the circuit for the opening of the oil contacts, thus allowing the linemen to go to work at once. Some other combinations of circuit breakers and disconnecting switches have been developed recently. One is a remote control multi-pole disconnecting switch interlocked with the cell doors. Another is a multi-pole remote control disconnecting switch interlocked with the circuit breaker mechanism so that the switch cannot be opened or closed while the breaker is energized.

Mr. Lawton: Following the remarks of Mr. Loizeaux, I wish to call attention to the fact that there are two types of design on switches of rupturing capacities from 250,000 to 300,000 kv-a. and voltages from 6600 to 22,000. One type provides vents above the oil, open at all times, while the other provides a vent with a check valve which is normally open, but which closes when the switch operates, thereby creating a pressure in the tank. Possibly the only way we will ascertain which type is the more effective is to await the results of experience, and I therefore urge that as many companies as possible send in reports on the operation of their circuit breakers, so that we may

gradually accumulate a fund of experience from which conclusions may be drawn.

THE CHAIRMAN: I wish to say another word on cooperation: I think it is necessary that all these various interests cooperate, as the cost of construction is so high now that it is seriously limiting the amount we can do; and unless we standardize and reduce the cost of construction, there will not be so much work as there was.

The next subject is the problem of generators. Mr. Albrecht, will you please present that subject?

H. C. ALBRECHT, Philadelphia: In the report of the Prime Movers Committee presented yesterday, there was a most interesting tabulation of the capacity of many of the large generating systems in the country, indicating the part of the capacity in units of 20,000 kv-a. and above, as well as the percentage of the total capacity represented by the largest unit of each company.

The very rapid increase in the number of generators in the past few years has brought with it the necessity of protecting them from the effects of external trouble and of minimizing the effects of internal trouble to a greater extent. The failure of a large unit usually means not only great expense for repairs, but even the temporary loss of its use may result in higher operating costs because older and less efficient units may have to carry the load otherwise carried by the large unit.

Because of this fact, increased attention is now being given to relay protection of a nature to disconnect the unit promptly upon failure, and to the question of the installation of fire extinguishing equipment, which will minimize the damage from generator break down, so that the unit may be repaired more quickly and cheaply.

The heavy loads carried by generators during the past two years, and the inability to take the units off the line for proper cleaning and inspection at the accustomed intervals, brought about by the heavy demands for power as the result of war conditions, have increased the number of generator failures and fires and thus emphasized their seriousness.

The Generator Sub-Committee has based its report upon information received in response to a questionnaire sent to 64

member companies operating generators of comparatively large size, replies being received from 30.

THE CHAIRMAN: Mr. Stahl, will you say a word?

N. STAHL, Providence, R. I.: There are several disconcerting elements in connection with generator fires. In the first place, to get from 30 companies a record of 81 fires, in so short a time as the three to three and one-half years appearing from the record, means that this subject has now an importance in central station operation which we have not heretofore observed. Further study of the statistics shows that there is need of even more such work. These fires seem to "know no breed or clan, nor creed nor birth," and they do not recognize size or voltage or particular make, nor age of machine, being equally disastrous under the widest range of conditions. Again, they occur just as frequently and just as seriously in the largest and most carefully managed companies where forethought in planning and skill in operation are at a maximum.

Your committee thought one feature should be particularly emphasized, namely the great need of increased care to keep the machines clean, and of more frequent inspection to ascertain their condition with respect to dirt.

Our Prime-Mover friends have long been aware that through a large machine in the course of an hour something like its own weight of steam passes, but it has not been so well understood that both with large water wheel generators and turbine generators, particularly where the ventilation problem is serious, there is also passed per hour air approximately equal in weight to the generator itself. If you can conceive of even a small fraction of 1 per cent of that air being laden with dust or oil, you perceive how great is the opportunity for the collection or settlement of that dirt or oil upon the windings and ventilation passages.

The manufacturers have brought out the fact that a fire is quite likely to result from oil laden dirt or dust or lint on the windings, if the voltage rises to from 175 to 200 per cent of normal which is a condition—as to the lower figure—occurring when an ungrounded system becomes grounded.

Your committee feels that this emphasizes the need of frequent cleaning and inspection.

In the matter of fire fighting, while pyrene and other chemicals have been used with fairly good success on smaller machines, the difficulty with large ones is to localize the seat of trouble and then to apply chemicals to it. So out of hard experience the operating companies have been forced to the use of two media. namely steam and water, both of which are inherently undesirable inside a generator. There is such a considerable diversity of opinion as to which of these is the better that your committee felt it unwise and inexpedient at this time to attempt to make you a recommendation between the two. The report gives in some detail both the past experience and prospective practice of respective companies for the two media.

In the case of our own company, we were so impressed by the seriousness of this subject that, although we had never had any generator fires and therefore no experience from which to choose between steam and water, we decided to take the bull by the horns and install apparatus so that we could use both, arrangement being made for the use of steam initially, but should that fail with any fire, we will then as a last resort be able to turn in water. This was done because we were impressed with the success obtained by the Duquesne Light Company of Pittsburgh in the use of steam, although most of that company's recent fires are of exterior origin and therefore not likely to be as difficult to extinguish as those arising within the windings. Further we had in mind the experience of the Public Service Company of New Jersey, where fire fighting by steam failed; so we felt that we would do well to prepare ourselves for all emergencies.

In the matter of cooperation and with further reference to the notion of a Bureau of Exchange localized in each sub-committee, your present committee would particularly welcome receiving, as time brings such experience to our companies, references to causes of fires, the means which have been found successful in preventing their spread, and the methods of actually fighting and extinguishing them.

H. R. Summerhayes, Schenectady, N. Y.: In the matter of protection, there has been objection to making automatic

switches on generators. But the differential relay is not automatic in case of overload, and operates only with unbalance or ground in the generator. It does not operate on any system disturbance.

So far we have yet to hear of a case where a differential relay failed to save the machine. There have been only a few machines equipped. A good many of the larger companies are considering the use of differential relays.

Mr. Stahl has called attention to the matter of keeping windings clean, which subject is assuming importance, since some fires have resulted not from short circuits but from sparks. Sometimes they may have come from mechanical friction or mechanical striking, the sparks lighting on this inflammable oil-soaked lint or dust. Fanned by the air blast they start a fire, so that it is advisable to put in fire protection in the form of steam or water.

The General Electric Company made some experiments a few years ago by constructing a ventilated steel box and putting in a number of coils. Fires were started in the box, and then methods to extinguish them were tried.

It was found that either steam or water was effective, but that when steam was used there had to be plenty of it. Since then instances have come to our attention in which fires have occurred, and all of the chemical extinguishers in the station were used without extinguishing the fire, so water was used as a last resort.

Instances have been cited where steam was used unsuccessfully. If you have a machine with 50,000 cubic feet of air going through per minute, and with the dampers closed there is 5 per cent leakage, a lot of air becomes mixed with your steam. The indication to us is that since water is used as a last resort, it might as well be used as a first resort. However, there is no doubt that steam will do the work if there is plenty of it, and the air is cut off.

Brief immersion in water does not injure your coils. They should be dried, however, as soon as possible thereafter.

THE CHAIRMAN: Has anyone else had experience along this line which would be interesting to the operating people.

H. B. POPE, Brooklyn: In regard to fires in the machines, I

think many of the companies, the Brooklyn Edison included, which have stopped the use of any lint that packs in the windings of ventilated machines, by using wipers instead of waste, have cut down the number of fires materially.

THE CHAIRMAN: The next division of our subject is "Power Factor Correction." We will ask Mr. H. L. Wallau of Cleveland to open this discussion.

(Mr. Wallau abstracted the Report of the Sub Committee on Power Factor Correction, to be found on pages 59, 60 and 61 and appendix pages 62 to 74 of the advance printed report.)

THE CHAIRMAN: The question of power factor correction is now open for general discussion. I would like to hear particularly from those operating men who have had experience with the various devices.

J. E. KEARNS, St. Louis, Mo.: While not a direct operating man, I had an interesting experience with the operation of three furnaces at the Charleston Projectile Plant at Charleston, W. Va. There were installed at this plant three 6-ton Herault furnaces, which apparently had been sold to operate at a power factor of from 80 to 90 per cent, which rating really means nothing to the operating man, as in this particular instance, the size of the central station was based on about 80 per cent power factor. It was found, however, that during the starting period the power factor ran as low as 30 to 40 per cent which naturally increased the required capacity of the plant. In view of this, it seems to me that the information contained in the report of the Apparatus Committee should bring out the fact that the power factor readings given for the furnaces are on the basis of the melting period, and in order to design your plant and lines properly, lower power factors than those tabulated should be taken into consideration.

H. A. WINNE, Schenectady, N. Y.: I would like to say a few words, Mr. Chairman, first on electrical apparatus for use in connection with electric furnaces and then on apparatus for arc welding. I think the majority of electric furnace loads are handled by the central stations with little or no difficulty. However, in some cases the current and power fluctuations are such as to cause disturbances to other loads in the system, particularly

where the total generating capacity is relatively small, or when the furnace load constitutes a large proportion of the total load on a long feeder. In such instances it is hoped that the "saturated core" reactor, which is now in the process of development, will offer a solution to the problem, and allow the central station to take on this otherwise desirable load without disturbance to its lines.

Briefly, this device consists of two similar transformers per phase, one winding on one being connected in series with the similar winding on the other and with the load. The remaining windings, one on each transformer or reactor, are excited from a source of direct current supply.

Such a reactor offers a low reactance to alternating currents so long as the alternating E.M.F. in the core is less than the direct E.M.F., but a high reactance to currents of a larger value, such that the alternating E.M.F. is greater than the direct E.M.F. That is, the maximum value of the alternating current can be limited to a relatively small percentage above normal, without having a large reactive drop at normal current. By adjusting the amount of direct current excitation the maximum value of the alternating current can be varied.

The following test results will give a clearer understanding of the way the reactor operates:

D. C. Excitation	A. C. Line Current	Volts Across Reactor
11.0 amperes	20 amperes	450 volts
11.0 "	30 "	2200 "
15.0 "	20 "	325 "
15.0 "	40 "	2200 "

In considering the above results, assuming that the line voltage is 2200, and that normal line current is 20 amperes, we find that with 11.0 amperes d.c. excitation, at normal line current the reactance is equivalent to 20 per cent, while at 150 per cent current it is 66.6 per cent; that is the current is limited to 150 per cent normal. If the d.c. excitation is increased to 15.0 amperes, then at normal line current the reactance is 15 per cent, and at 200 per cent line current it is 50 per cent; that is, the line current is absolutely limited to 200 per cent of normal.

Thus this reactor offers a means of limiting the maximum

value of current surges, without the disadvantage of a high reactance under normal conditions. The power losses in the reactor are exceedingly small, being only the I^2R loss in the two windings, and the core losses.

This system of current limiting may be used in either single or polyphase circuits, two transformers being required per phase. Two transformers are necessary in order to eliminate the second harmonic voltages which are induced in the reactor windings.

While, of course, the first cost of an installation of this character is somewhat higher than the cost of ordinary reactance coils, the advantages of the saturated core reactor are so marked that I believe it will be largely used.

A very recent and successful development in arc welding generators is a machine which has the same current and voltage characteristics at the arc as the constant energy balancer set described in the Apparatus Committee's Report. It, however, consists of only one armature and one field structure, complete in a single generator frame, no separate excitation current or exciter being required. This generator may be belt driven or direct connected to a direct current or alternating current motor, to form a motor generator set. It combines all the good points of the balancer set with the additional advantage that it does not require a 115 volt or 230 volt direct current circuit from which to be operated. It gives an open circuit voltage for striking the arc of approximately 60 with a welding voltage of approximately 20.

A range in welding current up to 200 amperes may be obtained by merely adjusting a dial switch. This machine is of course inherently a single operator welder, and so is intended to be used only for metallic electrode welding.

The Chairman: I suggest that we now take a recess of three or four minutes, before we take up the second part of our afternoon's work.

(Section reconvenes.)

The Chairman: We are fortunate in having Mr. Frank V. Magalhaes, the Chairman of the Meter Committee, with us. and he will now present his report.

REPORT OF COMMITTEE ON METERS

As the work of the Meter Committee this year has differed somewhat from other years, its report is also different, due mainly to an experiment instituted by the Executive Committee of the Technical and Hydro-Electric Section. The purpose of the experiment is to place the work of the Committee in the hands of the interested metermen of the Association well in advance of the convention, so as to insure a thoroughly informed audience prepared for full discussion.

The Meter Committee has been in accord with the plan of the Executive Committee and has made every effort to carry it through to a successful conclusion.

The material which was in the hands of individual members or sub-committees, even though in unfinished form, was compiled early in April and forwarded to about one hundred individuals throughout the country with the request that they present discussion at the convention on any of the subjects.

In judging the outcome of the experiment, it should be borne in mind that the committee year began only about three months ago, with the first committee meeting in February, 1919; further, that the war period broke the continuity of the Committee's work on several subjects, necessitating a fresh beginning with some consequent lost motion and added work.

WAR CONDITIONS AND PROBLEMS

The war problems in the various meter departments throughout the country were probably very similar. The Committee considered it of no particular significance or value, therefore, to analyze and discuss them in detail but merely lists them as a matter of future record and reference, or as they might have a bearing on the work in this period after the war. The essential war problems which, as stated above, were met by practically all the companies were:

The loss of trained testers and inspectors and the impossibility of replacing them.

The effort to train men or boys in a short time to carry on the work of experienced men.

Manuscript of this report was received April twenty-fifth.

The effort to train and use women in the Departments for testing as well as clerical work.

The loss of foremen or those in charge of divisions, necessitating reorganization and changes in the method of handling the work.

The extension, suspension or entire abandonment of various periodic schedules of testing and inspecting due to the lack of trained men to maintain them.

The necessity of change in the wage scales to meet the war conditions.

The difficulty and delays in obtaining apparatus and material of various kinds.

COURSES OF TRAINING FOR METER TESTERS

Conditions during the war period emphasized very acutely a need which had been realized in a more or less general way before the war. This need was for some definite course or method of instruction to train men to carry on the work in the Meter Department.

The large majority of companies in the country at the present time develop their new meter testers by a process of individual word of mouth discussion and contact with the older and more experienced testers. An increasing number of companies are coming to realize that this method is inadequate, first, because it does not develop testers fast enough to keep up with the demand; second, it does not produce a particularly good type of tester; and third, it does not screen out the men who, through indifference or incompetence, will never develop into good testers.

A well developed course of instruction in the hands of an able instructor, with periodic examinations to test the qualifications of the men, seems to be the conclusion reached by some of the companies to solve the need. The Meter Committee felt, therefore, that a sub-committee could profitably be appointed to look into the matter of existing courses and some material prepared by this sub-committee is given herewith. It consists of questions for the purpose of bringing out discussion, and outlines of three courses which seemed typical of seven or eight that were found to be in use by several of the companies.

In order to obtain the views of the various members of the

Association as to the best method whereby this could be done, we are submitting the following questions for discussion:

1. Is there a need for such a course as outlined?
2. Should this course be supervised by an instructor in preference to instructions from older or more experienced meter men?
3. Information which the Committee has received shows that better results are obtained when the men are trained under these suggested courses than when gaining their training under the experienced metermen. What has been your experience?
4. What is the best procedure for the meterman in training? Should he start testing on consumer's premises or in the meter shop?
5. Should the course be on the company's or employee's time, or should the company and employee share equally in giving their time for instructions?
6. Should the examinations be oral or written?
7. Should the training be universal for any position in the Meter Department, or should the employee be trained for a certain position?
8. Should there be any general lines followed to arouse competition among the men?
9. Is the Meterman's Hand Book given, sold or loaned to the employees?
10. What education should a man have before being employed in the Meter Department?

The following are outlines of typical courses selected from several that were found to be in use.

Course No. 1

Our method for training young men for meter testing has been as follows:

The helper is first sent out with a meter tester, in order to get acquainted with the general conditions of the work and the method of procedure followed in connection with the testing on the customer's premises.

He is then transferred to the meter shop where he works with an inside tester in order to get a better knowledge of the

mechanical construction of the meter, methods of adjustments and the causes of inaccuracies.

He is then sent outside again and works with one of the older testers, who spends a good deal of his time instructing him in regard to the general procedure of the test. After the tester reports to his foreman that the helper is getting a fair understanding of the work, he is allowed to test a meter or so a day under the direction of the tester. The foreman keeps in touch with his work and, as he becomes more proficient, the foreman gives him an examination to see if he is ready to start out by himself.

We made a rack on which we have mounted different types of meters which we use for demonstration purpos[illegible] n the older testers report that the helpers working with them are likely candidates for testers, one of the foremen will take several and have them demonstrate on the meters installed on this rack how they jump the different types of meters, how they make connections for testing, how they do the mechanical work on the meters and explain the general procedure followed in testing. The foreman will take up with them and explain different wiring problems such as meters and equipment wired incorrectly, including current coils wired in opposition, load connected to service side of meters, etc. The foreman will also assist them on any of the points on which they need further instructions.

The next step is for the foreman to give the helper a final examination, which he must pass to the satisfaction of the foreman before he is sent out by himself. This examination, which is an oral one, covers the work in general and includes questions regarding wiring, connections for test, maintenance work, testing formulae, filling out test cards, etc. Most of the questions are taken from the chapter in the Meterman's Hand Book, "Questions for Metermen."

After the helper has passed his examination and is sent out to work as a tester, the foreman keeps in close touch with his work and picks him up several times during the first month in order to give him additional instructions under actual working conditions.

During the three stages of his training he is attending the classes which we hold once a week for a twelve-week period. These classes are held each Monday evening and last an hour and

a half, three-quarters of an hour on the company's time and three-quarters of an hour on the employee's own time. They consist largely of a course of lectures and were arranged with a view of bringing out the practical points which a young man must know in order to test meters satisfactorily. In connection with the classes, an effort is made to encourage the young man to ask questions and bring up different points for discussion.

The following is an outline of the lessons:

1. Talks to the men in reference to their relations to customers and on the work of the Meter Department in general and the relation of the Department to other departments of the company [illegible] practical lessons in metering.

2. Elements of Electricity—
   Magnets,
   Electromagnets,
   Units of measuring,
   Definitions of ampere, volt and ohm,
   Ohms law, application of the law,
   Fundamental principles of a generator, etc.

3. Services—
   Service switches and cutouts,
   House fuses,
   Protective devices,
   Installation methods,
   Wiring diagrams,
   Meter locations.

4. Meter Construction, Direct Current Meters—
   Thomson Type M,
   Thomson Type C-6.

This includes the principle of operation, description of different parts, and internal connections of meters.

5. Meter Construction, Direct Current Meters continued—
   Thomson Type CS-2 and Type CS-3 meters,
   Thomson Type CS meters,
   Sangamo Type D-5 meter.

This includes the principle of operation, description of different parts, and internal connections of meters.

6. Testing Direct Current Meters—
    - Necessity for testing,
    - Frequency of tests,
    - Testing methods,
    - Instruments and equipment,
    - Procedure of test,
    - Testing formulae.
7. Testing Direct Current Meters—
    - Causes of inaccuracies, internal and external conditions,
    - Creeping,
    - Causes of creeping,
    - Methods of adjustments.
8. Meter Construction, Alternating Current Meters—
    - Single phase, induction meters,
    - Multiphase, induction meters.

This includes the principle of operation, description of different parts and internal connections of meters, current and potential transformers.

9. Testing Alternating Current Meters—
    - Frequency of tests,
    - Testing methods for single phase and multiphase meters,
    - Instruments and equipment,
    - Procedure of test,
    - Testing formulae.
10. Testing Alternating Current Meters—
    - Causes of inaccuracies,
    - Internal and external conditions,
    - Creeping,
    - Humming,
    - Causes of creeping,
    - Methods of adjustments.
11. Maximum Demand Meters—
    - Types of Demand Meters,
    - Principle of operation,
    - Classes of service to which they are adapted,
    - Inspections and tests.

12. Care of Testing Equipment—
    Calibration of instruments,
    Care in the use of instruments and equipment and precautions to be taken in their use.

In addition to the electrical and mechanical features of meter testing, we find it necessary to give the men a certain amount of instruction in regard to filling out test cards and making out reports satisfactorily, and during the classes on the procedure of testing on both direct and alternating current meters we spend some time on these subjects.

Course No. 2

Our training is divided into three general parts:

1. The apprentice is sent out as helper with an experienced outside tester for a period of six months.
2. Course of intensive training in the meter shop.
3. Outside testing work under the supervision of an instructor.

Work under the first division as helper consists of working under various men and on various classes of outside work. The helpers are expected to absorb as much information as possible and are given two written examinations, the first after one month and the second after two months' experience.

When the apprentice is transferred to the shop, a log sheet is started for him, on which is entered a record of the date; the kind of work to which he is assigned; the dates on which any coaching or instructions are given, and a brief note of their nature; who gives the instructions; and a record of the check tests taken on the tester's meters. The purpose of the log sheet is to systematize the coaching as well as to furnish a record of the progress and ability of the tester. This log sheet is referred to the superintendent monthly.

The apprentice is assigned to alternating or direct current work, as may appear best in the judgment of the shop foreman as the necessity of the work dictates. In some cases it may be best not to assign a tester permanently until foreman has become acquainted with his ability.

After a tester has been working two weeks in the shop, be is given one week's experience in the meter repair room. While

in the repair room he takes apart and reassembles at least one sample of each type of meter in use.

A direct current tester is given at least one week's experience on alternating current meters before being turned over to the Outside Testing Division, and vice versa. All testers are given two days' instructions in the laboratory in the method of testing direct and alternating current ammeters, voltmeters and rotating standards, and one day on demand indicator board. This instruction immediately precedes transfer of the tester to the Outside Testing Division.

It is not expected that the repair room and laboratory experience or the one week's experience of an A. C. man on D. C. work or vice versa will qualify testers in those branches. It is merely intended to broaden the view of the tester.

At the end of the first and fourth month, the apprentice is given a written examination. His answers are corrected by the foreman and coach, who then instruct him on the points on which his answers are unsatisfactory. A brief note of the result of the examination is made on the log sheet, and the examination sheets filed in the tester's envelope.

The plan at present in force for training apprentices provides for them to answer graded examination questions and be given special coaching while in the shop. The examinations are as follows:

First examination is given to helpers after they have had one month's experience.

Second examination is given to helpers after two months' experience.

Third examination is given to inside testers after one month's experience.

Fourth examination is given to inside testers after two months' experience.

Some further educational work is done by loaning the Meterman's Handbook to all new men, with a request that they refer to it on all puzzling questions which come up in practice.

The training in the shop is supplemented by an instruction book which we have prepared covering general principles of watthour meters, together with a detailed set of data and instructions

relative to all the types of meters which we use, including various troubles and their remedies and shop-testing routines. This instruction book goes into great detail and is intended to cover every point which might arise in the shop work. It is intended to be used as a parallel and aid to the shop instructor and also as a reference work.

When the apprentice graduates to outside testing, he accompanies an experienced man for the first week, and after that his work is carefully watched by the instructors or retest inspectors. We are at present conducting a class study of the N.E.L.A. Course on Practical Electricity which is purely voluntary and is attended by about twenty of our men; it is undoubtedly of real value. We did not attempt to make this class a part of the educational routine.

Course No. 3

Those employed to train for the ultimate position of meter tester must be over eighteen years of age and preferably have a high school education, or some practical knowledge of electrical work. They must at least have a grammar school education or one of equal grade.

The preliminary training of a meter tester is first in the position of an assistant. In this capacity he is assigned with experienced testers on the various classes of testing work. This gives an opportunity for the student to become familiar with the fundamental routine and details of the campany's practice.

The progress of the employee is reported periodically by the testers to whom he has been assigned, and if at the end of a specified time, which usually is from two to three months, the reports show that the employee is progressing satisfactorily, he is selected for the Vocational Training Course.

Before beginning the course the employee is told in detail the requirements and conditions which necessarily must be followed in order to complete the course satisfactorily. The employee is given to understand and made to realize thoroughly at the start that he is to be given an opportunity and that if he does not grasp it, the time spent would be wasted for the company and for himself, and he will be required to seek employment elsewhere.

The course as outlined begins with special reference to alternating current induction meters, the methods of testing and instructions in the use of the equipment required. The course is arranged in ten lessons, covering a period of two months, and the class meetings are arranged for 27 one-hour sessions. The entire course is given on the company's time, and competent experienced meter testers, generally foremen, are used as instructors.

In the class room a testing board is provided upon which are mounted different types and makes of meters, similar to those in service. The meters are installed, connected and wired exactly like customers' installations. The students, therefore, have the advantage of receiving instructions on meters and equipment operating under conditions similar to those encountered while testing meters in service.

At intervals, approximately every two weeks, oral and written examinations are given covering the work. The requirement is that each student must make a mark not lower than 70 per cent.

After completing the course final examinations are given, and if these are passed successfully the student is provided with suitable equipment for the testing of alternating current meters in service. For a period of one week he is accompanied by a selected experienced meter tester who determines if the man is competent to test alternating current induction type meters, starting on those of relatively small capacity.

The tester reports the progress of the employee during this week of training and, if the work is satisfactory, the student continues on his own responsibility for a minimum period of not less than two months. At intervals during this time the student is given oral examinations and is visited occasionally while testing on customer's premises.

The final step in the employee's training includes two months in the meter shop. This covers the testing of large capacity alternating current meters, the testing of direct current meters and general experience in repairing and reconstructing meters.

The employee is then placed in a permanent position as meter tester and advanced further in accordance with his ability and development.

1—General.

(a) Address by the Superintendent of the Division, giving broadly the purpose of the course and the outline of the plan.

(b) References for study:
Metermen's Handbook N.E.L.A.
Electrical Meters, Jansky.
Applied Electricity for Practical Men, Rowland
Engineering Department Handbook.
Meter Code, A.E.I.C.

2—Units and Definitions.

(a) Definitions of fundamental units, amperes, volts, watts, etc.

(b) Applications of units and practical problems.

3—Watthour Meters

(a) Watthour meters, description, functions and nomenclature.

(b) Rating, amperes, volts and wire of the meter.

(c) System of numbering the meters serially.

(d) The test constant and register constant.

(e) The meter register and its function.

(f) How to read meters.

4—Standard and Testing Equipment.

(a) Instruments and auxiliary equipment for testing. Description and function of the rotating standard. Loading devices and use of tools.

(b) The care of the instruments, equipment and tools.

5—Connections of Meters and Testing Equipment.

(a) Rotating standard.

(b) Loading devices.

(c) The interconnection of the meter, rotating standard and load device.

(d) Connections of apparatus to the circuit.

(e) Meter connections to circuit and load.

6—Calculations.

(a) Determination of the ratio of the meter revolution to the revolutions of the standard.

(b) The testing formula, calculations and application of mathematics.
(c) Instruction in use of the slide rule.

7—Records and Reports.
(a) The importance of accurate, thorough and reliable records and reports.
(b) Special reports of conditions encountered.
(c) Description and use of the department forms.
(d) Method of recording results of test.

8—Testing of Meters.
(a) Inspection of service wires and meter connections.
(b) Explanation of tampering, cases and methods of detection.
(c) Records to be made before meter is opened.
(d) Cleaning of cover and interior of meter.
(e) Connecting of equipment to the meter.
(f) Interruptions to customer's service.

9—Determination of Meter Accuracy.
(a) Loads to be used.
(b) Method of determining the accuracy of the meter under test.
(c) Accuracy limits.
(d) Causes of meter inaccuracy.
(e) Detection of faults and how to remedy.
(f) Calibration of meters to proper accuracy.
(g) Adjustments.

10—Installation and Metering Methods.
(a) Standard types of meter installations.
(b) Protective devices and standard testing blocks for safety and ease of testing.
(c) Standard methods of wiring various types of meters.
(d) Class of service to be metered.
(e) Kind of contracts.

CONCLUSION:

1—Written and oral examinations covering the course.
2—Department instructions to employees.

3—Attitude of meter testers to customers.

4—Instructions in service meter testing with experienced meter testers.

5—Instructions in meter shop, repairing and testing new and used meters.

BRIEF COURSE FOR METERMEN

In connection with the foregoing discussion of courses prepared by companies for training their meter testers, it seems of value to report concerning a short course for metermen, which was held at the Iowa State College at Ames, Iowa, in February, 1919. An outline of the way in which the course was conducted was obtained from Prof. T. D. Paine, who states that the questions were based largely on the data in the Electric Meterman's Handbook:

Preliminary:—Letters were written to all electric light and power companies in Iowa asking them to send men. It was specified that the course would be only four days in length and would take up only two-wire meters. Some twenty companies responded, stating they would send one or two men.

Cost to Metermen:—No expense except board and room. Tuition was free.

Registration:—Thirty-five men registered from various parts of the state. They all asked for instructions relative to two-wire single-phase meters.

Equipments:—Watthour meters, rotating standards, loading devices from manufacturing companies. To these were added lamp bank loads and metermen's repair kit tools and apparatus.

Arrangement of Wiring:—Benches with backs were arranged on two sides of a large room. Service switches and fuse blocks were wired to service wires, but meters were not wired in. The meters, when wired in, were connected as in service. Two men worked together on one meter.

Methods of Instructions:—Lectures, testing, questions for outline.

Periods of Instruction:—8 A.M. to 9 A.M., 1 P.M. to 2 P.M.

Periods for Testing:—9 A.M. to 12 M., 2 P.M. to 6 P.M.
Lectures by Meter Experts:—Evenings.

Outline of Instruction and Testing:—First lecture, fundamental units of electricity, such as amperes, volts, resistance, frequency, etc.

Test Period:—Taking various meters apart and studying the important features of construction.

Second Lecture:—Construction of watthour meters, showing by demonstrations the purpose of each part. Test period, assembly of meters.

Third and Fourth Lectures:—Full load, light load and power factor adjustments on different makes of meters. Test period; wiring of meters and examination and changing of full and light load adjustments. Wiring in of rotating standard.

Fifth and Sixth Lectures:—Method of testing meter by comparing with rotating standard. Calculation of per cent registration. Test period: continuation of above.

Seventh and Eighth Lectures:—Factors which affect registration of meter in service, repair of meter, etc. Test period: various faults were placed in meters and the metermen had to locate and remove them.

Evening Meetings:—Lectures and discussions by meter experts from manufacturing companies. Very interesting discussions followed these lectures.

General Opinion of Those Concerned:—Results satisfactory. Some have asked that longer and more advanced course be offered. Others want courses twice a year. Some want work on maximum demand and indicating meters; some want work on polyphase and 3-wire meters.

The Engineering Extension Department believes that it can work out successful courses along these lines. It is likely that the future courses will cover a longer period and will include all kinds of testing, so that a student can arrange to take just what he desires. It may also be arranged that the courses will be offered in the larger central cities throughout the state, where groups of sufficient number can be secured to warrant the course. The College is receiving reports from day to day giving the ideas of the men as to what they wish.

INSTRUMENT TRANSFORMER

Test Practice and Performance

In order to determine the practice of the various member companies with regard to instrument transformers, the Committee sent communications to a number of the member companies and to manufacturing companies asking for information relative to the methods employed in testing, the frequency of test, and other factors affecting the usage of instrument transformers.

Considerable diversity was found in the test methods employed, and in only two or three instances was there anything in the way of new developments. The proposition of testing transformers was taken up in considerable detail in the Meter Committee Report for 1916. Several methods both for current and potential transformers are given in this report, and many of the member companies reported the use of one or more of these methods.

In summarizing the situation, it may be said that the manufacturer's laboratories and the commercial standardizing laboratories incline toward the use of primary test methods, i.e., methods by which the constants of a transformer are determined directly from measurements on the transformer itself. The operating companies, however, quite generally reported the use of secondary methods, that is, methods in which a transformer is tested by comparison to a standard transformer that has previously been standardized by a primary method.

Primary Methods

Of the primary methods the one most frequently reported was the so-called shunt or potentiometer method.

For potential transformer tests by this method a non-inductive resistance of large value is connected across the primary of the transformer to be measured, and the secondary voltage is balanced against the voltage drop across a portion of this resistance. The ratio then is, practically speaking, proportional to the total value of the resistance divided by the portion connected to the secondary circuit.

For current transformer tests by this method, a fixed non-inductive resistance is inserted in the primary circuit of the transformer under test, and an adjustable non-inductive resistance

in the secondary. The test is made by adjusting the secondary resistance until a balance is obtained between the voltage drop across this resistance and across the primary resistance. Under this condition the ratio is inversely proportional to the values of resistance in the primary and secondary circuits.

In a general way this explains the principles of the potentiometer method in so far as ratio tests are concerned, but many additional factors must be taken into account in making the tests to secure a proper balance. The voltage drops in the primary and secondary circuits of the test apparatus are usually not exactly in phase and to bring about the condition of exact balance, a quadrature component is introduced in the test circuit to balance the components of the differences which cannot be balanced by direct opposition. By computing the value of this quadrature voltage, the phase angle as well as the ratio of the transformers under test may be determined.

The greatest variation in the potentiometer or shunt method as reported was in the type of indicator or detector used to determine balance; at least three different kinds of instruments are used for this purpose. The Bureau of Standards employs a vibration galvanometer, i.e., a galvanometer sensitive to alternating current. The Electrical Testing Laboratories employ a direct current galvanometer with a synchronous contactor in its circuit, the function of this contactor being to reverse in direction each half-cycle. This practically rectifies the alternating current voltage waves and gives a continuous current for the galvanometer circuit; hence the direct current galvanometer may be employed. The third kind of indicator reported was a separately excited dynamometer connected to a phase shifting transformer. This device is sensitive to alternating current and its excitation is adjusted in phase position by means of phase shifter to give the required test values for ratio and phase angle determination.

One large manufacturing company reported the use of the mutual inductance method for testing current transformers. This method resembles very closely the potentiometer method referred to, except that inductances are introduced in the primary and secondary respectively of the transformer under test, that for the secondary circuit being adjustable, and a balance is obtained for the voltages induced on the secondary of these inductances.

The advantage claimed for the mutual inductance method as compared to the shunt or potentiometer method is that a much higher voltage can be utilized for the indicator circuit, without loading the transformer appreciably. The indicator used by this manufacturer is a direct current galvanometer with a synchronous contactor.

One method reported by a member company that may be considered a primary method is the Test Ring Method. This is described in the A.I.E.E. Proceedings for September, 1918, page 1173, in an article by Mr. H. S. Baker. In its application a special transformer or test ring is connected with its primary and secondary respectively in series with the primary and secondary of the current transformer under test. The number of turns in the secondary of the test ring is varied until they balance the number of turns in the primary and the ratio of transformation is then inversely proportional to the number of turns in the primary and secondary circuits. The method of determining the balance is by the use of a separate or exploring winding on the same core as the test windings. When there is an unbalance in the two test windings, there will be a resultant flux which will induce a voltage in this test winding. In general it is not possible to obtain an absolute balance, and both ratio and phase angle may be determined from the voltage in this winding by using for measurement a special wattmeter with excitation current from at least two phases of a polyphase source of supply. For the exact method of making the test and of making calculations, the reader is referred to the article mentioned.

One large manufacturer reports that constants for potential transformers were calculated from formulæ given in the Bureau of Standards' publication No. 211, based upon accurate measurements of resistance, reactance, iron loss, exciting current, and ratio turns.

Secondary Methods

One member company reports considerable advance and development in a new secondary method termed the differential method. This is similar to the indicating wattmeter method described by Mr. H. B. Brooks in Bureau of Standards' Publication No. 217. The member company, however, has developed the

method to a much greater extent and has constructed a special testing instrument so that the method may be used for either current or potential transformer tests.

Briefly described, comparison is made between a transformer under test and a standardized transformer of the same nominal ratio by measuring the vector difference in current or voltage (current for current transformers and voltage for potential transformers) on a separately excited dynamometer of high sensitivity. Under the most favorable test conditions, a two-phase or quadrature source of excitation is employed, and the instrument is so calibrated that in the case of potential transformer tests differences in ratio and phase angle of the transformer under comparison may be read directly from the scale of the instrument. The correct test values for the transformer under test are then obtained by adding or subtracting these differences to the constants for the standard transformer.

For current transformers, the instrument is not calibrated so as to be direct reading for all values of secondary current. It is necessary to multiply the scale reading by a constant, depending upon the values of secondary current for the test conditions.

The advantages claimed for this method are the ease and the small expense at which the tests can be made. Its accuracy is sufficient for all commercial purposes, as has been determined by careful checks against recognized standardizing laboratories. Because, beyond the adding of correction factors to the constants given for the standard transformer, and in some cases multiplying these values by some even figure, all calculations are eliminated, the method is more rapid in its application than any method having a high degree of accuracy previously devised.

When employing the differential method, either current or potential transformers may be tested for ratio from a single phase source; but a polyphase, preferably a two phase, source of e.m.f. is required for phase angle determination.

Summary of Testing Practice

Nearly all of the companies represented by members of the Committee are testing prior to their installation all current and potential transformers used in connection with watthour meters measuring energy for billing purposes. The tests include meas-

urements for ratio and phase angle, as well as tests for polarity and insulation.

Two companies have their transformers checked by a recognized testing laboratory when purchased and before reinstallation in cases of removal.

Two companies are using a ring method already described. Eight are employing the 2-watthour meter proposed by the Bureau of Standards, and one company is using a differential method for determining ratio and phase angle deviations, while two companies are using comparison methods with known standards as a ready means of determining approximate ratio values and to detect large errors.

Summary of Test Results:

The Committee has endeavored to secure from the member companies information relative to the results obtained in transformer testing as regards uniformity of product and the effect of aging. Data have been received from both the manufacturing and operating companies. The Committee has carefully reviewed this information and is submitting herewith summaries of the data obtained.

CURRENT TRANSFORMERS

One operating company submitted data of tests made on over 300 current transformers of different types. The two rotating standard method of testing was employed in making the tests, but the accuracy figures here given are not expressed in terms of ratio of primary amperes to secondary amperes. These figures represent the rate at which a meter initially correct would run if connected to the secondary of the transformers. The average values as taken from the series of tests are given herewith.

TYPE OF TRANSFORMERS

	D-20	E-18	K-5	K-28 K-48	K-55
No. of transformers	62	40	54	83	149
Full Load					
(a) Average accuracy..	101.5	101.5	100.1	100.8	100.7
(b) Average deviation from (a)........	.4	.2	.1	.1	.2
(c) Max. deviation from (a)	1.0	.5	.6	.7	.5

No. of transformers	D-20 62	E-18 40	K-5 54	K-28 K-48 83	K-55 149
10% Load					
(d) Average accuracy	101.5	101.4	100.2	99.8	100.2
(e) Average deviation from (d)	.6	.3	.4	.3	.2
(f) Max. deviation from (d)	1.7	1.1	1.5	2.7	.8
P.F .5 Full Rating Current					
(g) Average accuracy	102.0	102.3	101.1	100.8	101.1
(h) Average deviation from (g)	.7	.6	.5	.4	.5
(i) Max. deviation from (g)	2.2	1.1	1.1	1.5	1.5

Another operating company submitted results of tests on fifty each of three types of current transformers selected indiscriminately and tested under identical conditions. The following is a summary of the results:

	Per Cent Current Rating	——Per Cent Ratio Accuracy—— Type W2	Type K48	Type K28
Minimum	5	99.48	99.36	100.05
Maximum	5	100.69	100.97	101.80
Maximum Deviation	5	1.21	1.61	1.75
Minimum	10	99.46	99.33	99.66
Maximum	10	100.53	100.50	101.30
Maximum Deviation	10	1.07	1.17	1.64
Minimum	100	99.41	98.71	98.48
Maximum	100	99.95	99.59	99.75
Maximum Deviation	100	.54	.88	1.27
		Phase Angle		
Minimum	5	+ 14′	— 8′	— 5′
Maximum	5	+ 50′	+ 51′	+ 30′
Maximum Deviation	5	36′	59′	35′
Minimum	100	— 1′	— 11′	— 17′
Maximum	100	+ 11′	+ 7′	+ 1′
Maximum Deviation	100	12′	18′	18′

The current rating of the W-2 Transformers ranged from 15 amperes to 800 amperes, that of the K-48 Transformers from 5 amperes to 200 amperes, and that of the K-28 Transformers from 40 amperes to 600 amperes.

Potential Transformers

A report on the uniformity in test values of potential transformers was made by one member company. Fifty each of two types of potential transformers were selected indiscriminately and tested under identical conditions. The following is a summary of the results:

	Per Cent Load	Per Cent Ratio Accuracy Type ND	Type CQ
Minimum	0	98.92	99.36
Maximum	0	100.88	100.14
Maximum Deviation	0	1.96	.78
Minimum	100	100.33	100.33
Maximum	100	101.93	101.82
Maximum Deviation	100	1.60	1.49

The type ND transformers were rated 600 volt-amperes, 20 to 1 ratio, and the type CQ transformers were rated 200 volt-amperes, 70 to 1 ratio.

Defective Transformers

While the majority of transformers of approved types are within proper limits of accuracy and properly insulated when received, some member companies report the occasional receipt of transformers not within the allowable limits of accuracy, and in some cases transformers are found defective in insulation.

Period of Tests

In many cases the member companies have a five-year period of test for instrument transformers of various types, although it is the practice of one company to test current transformers over 200 amperes capacity and all current and potential transformers used on primary installations every three years, while other instrument transformers are tested every five years.

The Public Service Commission for the First District of New York on May 23, 1917, made the following ruling—Case No. 2202, *Section* 13. In periodic or office tests, the calibration certificate of the transformer or the shunt shall be dated within a period of ten (10) years preceding the time the meter is tested. *Section* 14. In complaint tests, the Commission will accept the calibration certificates of the transformers or the shunts, provided they are dated within a period of one year preceding the time the meter is tested.

Member companies coming under the jurisdiction of this District are operating on the approved ten-year schedule. It is also their practice to test all transformers before reinstallation and to make special tests in the case of complaints.

Results of Periodic Tests

Most of the companies throughout the country report that a comparatively small number of instrument transformers have

been retested on a periodic basis, owing to the number of years between the testing periods and to the fact that the time for retests for a number of companies is about due, also that few schedules have been fully maintained during the war period. There is, therefore, but little information available from which to draw conclusions.

One of the member operating companies submitted records of a series of tests made on thirty-one D-20 current transformers at intervals of from five to nine years. The average interval between tests for the thirty-one transformers was 6.7 years.

This company employs in testing the two rotating standard method. In the results submitted, accuracy is expressed in terms of the rate at which a meter initially correct would run if connected to the secondary of the transformer. Following is a summary of the entire series of tests:

PERCENTAGE OF ACCURACY

Years Interval Between Tests	Full Current Load, Unity Power Factor		10% Current Load, Unity Power Factor		Full Current Load, 50% Power Factor	
	1st Test	Last Test	1st Test	Last Test	1st Test	Last Test
Av. 6.7	101.35	101.39	100.60	100.46	101.63	101.58

One of the large manufacturing companies submitted results on a total of thirty-seven transformers which had been tested and retested at intervals ranging from one to seven years. The maximum deviation in ratio accuracy between the initial and the final tests on these transformers was 0.4 of 1 per cent, and in phase angle 25 minutes.

An operating company submitted results of retests of forty-four transformers of various types, taken at intervals from less than one to more than seven years. The results of these tests are given in the following tabulation:

Form	Rating Amp.	No. Trans.	Average Period Between Tests		Average Percentage Change in Ratio		
			Yr.	Mo.	10% Current Rating	50% Current Rating	100% Current Rating
E-18	3000	4	1	4	+ .21	+ .15	+ .08
D-20	200-600	10	2	7	+ .20	+ .10	+ .13
K-6	200-400	10	3	7	+ .45	+ .62	+ .59
K-8	30-800	10	4	9	— .30	— .04	— .19
K-28	400	10	2	0	+ .52	+ .39	+ .34

Change in Phase Angle 10% —.24% —14% —.10 —03 14

The results submitted do not show any marked change in transformer accuracy due to aging, but the number of tests is not sufficient to warrant any conclusions.

Methods of Applying Corrections to Instruments and Watthour Meters When Used in Connection with Instrument Transformers

For applying corrections to instruments and watthour meters used in connection with instrument transformers, some member companies are using formulæ which are easier to apply than those previously presented, and at the same time sufficiently accurate for the purposes desired. Calculations by these short-cut formulæ become a mental instead of a long-hand operation. They are easily understood and can be readily employed by the average meter tester. Their accuracy is closer than 0.05 of 1 per cent in the case of transformers, acceptable in accordance with the regulations of the meter code, that is, transformers whose accuracy is within 2 per cent. They are given herewith in detail.

Condition No. 1—Using One Transformer Only

Procedure:

(1) Determine the percentage of accuracy of the transformer ratio by dividing the ratio obtained in test by the nominal or rated ratio and multiplying this result by 100.

(2) Set the meter as an individual meter to run at this percentage of accuracy.

Example: Assume that a transformer, the nominal ratio of which is 40 to 1, shows in test at a given load an actual ratio of 40.2 to 1. The percentage of accuracy in ratio is

$$\frac{40.2}{40} \times 100 = 100.5 \text{ per cent}$$

The meter for this point then should be set for 100.5 per cent accuracy.

Accuracy at Other Points:

It is not always possible to set a meter so that it will give an accuracy of 100 per cent throughout its entire load range when used in connection with a given transformer. The percentage of accuracy at any point may be determined, however,

when the accuracy of the transformer ratio and of the individual meter are both known.

Formula: Combined accuracy of transformer and meter = percentage of meter accuracy + 100 per cent — percentage of transformer accuracy.

Condition No. 2—Using both Current and Potential Transformers

Procedure:

(1) Determine the combined accuracy of current and potential transformers by the following formula: Combined accuracy = per cent of accuracy of current transformer + percentage of accuracy of potential transformer — 100 per cent.

(2) Set the meter as an individual meter to run at this percentage of accuracy.

Example: Assume that the percent of accuracy of the current transformer is 99.6 and that per cent of accuracy of the potential transformer is 98.5. The combined accuracy then = 99.6 + 98.5 — 100 = 98.1 per cent.

Accuracy at Other Points

For the same reason that a meter cannot always be set to give an accuracy of 100 per cent throughout its whole range when used in connection with a current transformer, it cannot always be so set when used in connection with both current and potential transformers. The combined accuracy of current transformer, potential transformer and meter under the above conditions, may readily be determined by the following formula:

Combined accuracy = percentage of meter accuracy + 100 per cent—combined transformer accuracy.

The above formulæ follow very closely those given in the 1917 Meter Committee Report, but the calculations involved have been simplified.

Magnetization of Current Transformers

Some data were submitted giving the results of special tests on current transformers to determine the effect of magnetization. In these tests the effect of magnetizing by three different means was investigated:

1—By opening the secondary circuit with full rated current in the primary circuit.

MAGNETIZATION CAUSED BY OPENING SECONDARY

	Per Cent Current Rating	Form K28	Form K48	Form K65	Form W2	Form 3	Type KA	Type KB
Change in Ratio	10%	+.41%	+.25%	+.12%	+.18%	+.17%	+.17%	+.16%
" " "	100%	+.24%	+.14%	+.10%	+.03%	+.14%	+.09%	+.10%
Change in Phase Angle	10%	+2′	+3′	+2′	+2′	+11′	+3′	+6′
" " " "	100%	+1′	+2′	+1′	+1′	+6′	+2′	+2′

MAGNETIZATION CAUSED BY CURRENT OVERLOAD

Change in Ratio	10%	+.22%	+.32%				+.57%	+.54%
" " "	100%	+.08%	+.05%				+.15%	+.15%
Change in Phase Angle	10%	+5′	+1′				+12′	+8′
" " " "	100%	+2′	+1′				+5′	+3′

MAGNETIZATION CAUSED BY PASSAGE OF DIRECT CURRENT

Change in Ratio	10%	+.42%	+.22%				+.47%	+.50%
" " "	100%	+.12%	+.09%				+.19%	+.15%
Change in Phase Angle	10%	+11′	+4′				+13′	+7′
" " " "	100%	+3′	+1′				+4′	+4′

From these somewhat scanty results it appears that magnetization due to an excessive current overload with the secondary closed, or due to the passage of direct current through the windings, is more severe than that caused by opening of the secondary in the load. The Committee feels, however, that this matter should be given further investigation and study, and these results and tentative conclusions are advanced for discussion.

2—By passing 10 times rated current through the primary circuit with the secondary circuit closed through a resistance that represented full load for the transformers.

3—By passing rated direct current through the secondary winding.

A table showing the results of these tests is given herewith on page 454.

MEASUREMENT OF MAXIMUM DEMAND

The question of maximum demand measurement was referred to a sub-committee to investigate and report on any new methods or devices that might have been adopted or developed during the past two years.

The sub-committee made a survey and reported that the manufacturers had not undertaken new developments to any great extent during the war period. A survey of some of the operating companies and the technical press indicated not so much a development of new methods of measuring maximum demand energy as a more careful consideration of such measurement, taking into account the inductive character of the load.

Below is a list which represents methods in use or methods suggested for use and advanced here purely for the purpose of discussion:

(1) The use of graphic power factor meters in connection with watthour meters and maximum demand devices.

(2) The above use of graphic power factor meters may be periodic, either on a daily, weekly or monthly basis, or as a permanently installed part of the metering equipment.

(3) The use of two single phase watthour meters for obtaining a record of the average power factor on a three phase circuit, these meters being like the graphic instruments referred to above in addition to the regular energy metering and demand equipment.

(4) The use of a portable equipment consisting of two single phase watthour meters to make surveys of power factor conditions in consumer's premises on a periodic basis.

(5) The use of meters connected to measure the inductive component either with or without a demand device.

(6) The use on a single phase basis of an ampere hour meter, either with or without a demand attachment and a recording voltmeter.

(7) The use of some form of kv-a. hour meter with a demand attachment. Some of the manufacturers report investigation and some progress along the lines of a kv-a. hour meter.

A survey was made of a number of the operating companies to determine the type of demand apparatus in use, and sixteen companies advised that the following types of demand meters are in use at the present time:

4	Using	Wright Demand meters		
1	"	Type H	"	"
2	"	Maxicator Demand meters		
8	"	M-2, M-4 and M-5 Demand meters		
1	"	Type W Demand meters		
2	"	Type G	"	"
7	"	Type P	"	"
1	"	Relay	"	"
3	"	Type R. O. Demand meters		
6	"	Graphic & Curve Drawing		
3	"	Type R. A. Demand meters		

BUREAU OF STANDARDS—MAXIMUM DEMAND

The Bureau of Standards announced through a representative at one of the meetings of this Committee, in February, 1919, that it was proposed to revise Circular 56 (of the Bureau of Standards) and include a section on maximum demand.

PERIODIC TESTS OF WATTHOUR METERS

During the war period, conditions were such that the operating companies were forced either to extend or suspend entirely the schedules for periodic test of watthour meters.

The Meter Committee, in resuming its work after the war period, considered that there might be data available among the companies that would show if meters of various types could not

safely be allowed to run for longer intervals between tests than those maintained prior to the war.

The brief period of committee activity to date has not permitted any survey or analysis to be made, so the question is presented herewith for the purpose of developing discussion and possibly to permit the compilation and presentation of actual data bearing on this point by some of the members at the convention.

FUSING POTENTIAL TRANSFORMERS

Question has arisen at different times in committee meetings as to the practice of fusing potential transformers used with watthour meters.

The fuses used on potential transformers to serve the purpose as a fuse are liable to be light and fragile. The loss of a fuse either mechanically or electrically means the loss of the element on one phase. With a load of inductive characteristics, that particular phase might be carrying a relatively small percentage of the total load. For this reason, the blown fuse might go undetected for a considerable period with a consequent significant loss of revenue.

Question arises, therefore, as to the desirability of eliminating the fuses on the potential transformers. A survey of the Committee itself indicated that 80 per cent of the companies represented use potential transformers unfused on meters on circuits of 6600 volts or less.

The suggested use of a limiting resistance in the primary in place of the fuses is a questionable practice from the standpoint of introducing possible errors.

The questions are, therefore, presented herewith for the purpose of bringing out the reasons for or against the practice of fusing potential transformers.

SECTION X OF THE METER CODE

Work on the remaining parts of this section practically ceased during the war period, but authorization has been obtained to continue it and the work has been resumed by the Electrical Testing Laboratories which are preparing the material with a sub-committee of the Meter Committee. There is nothing in finished form to report at this time.

METER LECTURE

A meter lecture has been in preparation by the two Meter Committees preceding the present one, and efforts have been made to summarize the large amount of material which has been gathered and condense it into a practicable and adequate lecture for the purpose in mind. The lecture is still not complete, and, while the Committee reports progress, it can also report that the real difficulty is that the voluminous amount of material in hand is probably sufficient for a sêries of two or three lectures rather than a single one.

POTENTIAL SWITCH FOR ROTATING STANDARD TEST METER

The Committee still reports the lack of a satisfactory potential switch for controlling rotating standard test meters. This switch is an essential part of the testing equipment used by practically all the companies. It does not seem necessary to repeat the necessary features of such a switch as they have been well understood by the manufacturers for some time. Briefly the switch should be rugged, simple in construction and of a reasonable cost. The Committee recommends to the manufacturers that in undertaking development work again they give some consideration to the development of such a switch to fill an existing and long-continued want.

NEW DEVELOPMENTS

The Committee finds after thorough inquiry among the manufacturers that, as might have been expected, there was very little development work undertaken or carried on during the war period. Report is made of one or two modifications to existing apparatus and one or two new developments that seem of interest at this time.

The widespread use of maximum demand apparatus requiring accurate timing and synchronous operation renders very interesting the development of the Warren Timing Element and system which are reported in this section.

THE WARREN TIMING ELEMENT

The Warren self-starting synchronous motor embodies a very accurate time-keeping element in the space of 2⅛ by 2⅝ by 2⁹⁄₁₆ inches capable of delivering more power than many of

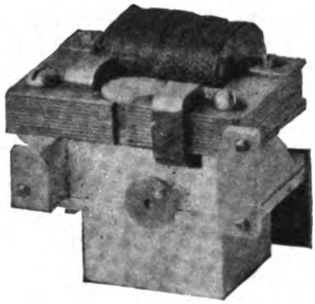

FIG. 1—WARREN MOTOR TIMING ELEMENT

the present spring-driven clocks, and this without the usual weekly or monthly winding. (See Fig. 1.) It is, therefore, particularly adapted for use in graphic and demand meters, time switches, etc., where the advantages of a time-keeping element with such characteristics are obvious. An even more important asset, for certain applications, than any of those mentioned, is that it is possible to synchronize the records of graphic or demand meters—a feature which heretofore has been very difficult to accomplish.

Its simplicity and the elimination of the usual amount of skilled attention which the spring-driven clock requires are of importance from a metering standpoint.

The small timing element can be installed in any device connected to the alternating current mains of a company where constant speed and synchronous operation are desired. The element itself, when combined with an accurate clock, can be used as a master clock at the central station both for providing uniform time throughout the system and for regulating frequency. The construction and operation of this Warren master clock are described in detail below:

In the master clock are two separate and independent elements. One is a very accurate pendulum type of clock, the other a small synchronous motor. There are also two independent "second hands" which rotate about the same shaft over the operating dial in clock fashion. One of these hands (the black one) is driven by the pendulum clock, while the other (gold in color) is driven by the synchronous motor. The gearing between the synchronous motor and the hand which it drives is so ar-

ranged that when the frequency of the generator to which it is connected is correct it will make one revolution in five minutes. Likewise the clock-driven hand is geared to make one revolution in five minutes.

Obviously if the frequency is correct, these two hands, if started one over the other will rotate at the same speed and remain together. If the frequency is high, the motor-driven hand will gain, and if low, it will lose with respect to the clock-driven hand which, of course, keeps correct time. The operator's duty is to keep the two hands together by adjusting the speed of the prime movers. It is evident, from a consideration of the principle of this device, that instantaneous fluctuation in frequency will not appear on the dial. Furthermore, momentary high values may be cancelled by corresponding low values of frequency, so that it is only a continued error in the average frequency which will cause the hands to depart from one another. Therefore, under ordinary conditions the clock need be observed only once in a period of about fifteen or thirty minutes. The synchronous motor is also geared to the main spring which drives the clock, so that it requires no attention, except the regular comparison with Washington time signals.

While this system offers an easier and more accurate method of controlling the frequency than by means of the usual type of frequency meter, its particular interest from a metering standpoint lies in the use of the Warren synchronous motor in the place of the usual spring-driven clock movement. Any synchronous motor connected to an alternating current system, as we know, must run "in step" with the generator which supplies the power. No matter how we may alter the speed of the generator, all motors connected to that system are effected in the same way. Therefore, if the generator is run at an average speed, which is held absolutely the same from day to day by means of a master clock, then all synchronous motors connected to that generator run at the same speed and can, therefore, be used as accurate time-measuring devices.

The Committee found that this development was relatively new to most of the operating companies, but that a few of the companies had had some experience with it. It is appreciated that the summary of this experience as given below is somewhat

fragmentary and meagre, but it seems of sufficient value to report, inasmuch as it represents actual experience.

Company No. 1. This company has the master clock feature installed at its central station for regulating frequency, and, in addition, has a considerable number of graphic recording voltmeters equipped with the small timing element, and is experimenting with a small number of timing switches for street lighting and timing devices for maximum demand indicators. The experience to date, briefly summarized, is very satisfactory indeed from the standpoint of the accuracy of the timing device, but indicates the necessity for simplification as to gears, etc., in some of the adaptations of the Warren device to existing types of instruments designed for other timing elements.

Company No. 2. Some fifteen months ago this company received a master clock and one secondary clock. At that time the generating capacity was somewhat limited, and five or six large electric furnaces so disturbed the frequency that the results of trying to regulate it were very unsatisfactory. About nine months ago a new power house was completed, and since that time the frequency has been accurately regulated by the Warren system.

One type G indicator was equipped with the synchronous motor clock and geared to rotate the chart once each sixteen days, thus requiring but two trips a month to the indicator.

Company No. 3. The company has had a temporary master clock installed at its central station and is now putting in permanent equipment. It has approximately 70 secondary clocks installed in special demand meters, replacing double spring-driven ten-day clock movements. One motor is installed in a type C-4 graphic meter having a reroll attachment. Sufficient torque is developed to drive all of these instruments with ample surplus, as demonstrated by the fact that the charts will tear if they bind, before the motor will stop. During the winter months some trouble was experienced in devices exposed to the cold, due to the oil thickening, but this was overcome by substituting kerosene for the standard oil. The clocks are invariably exactly on time, except for the rare cases in which the line is out of service or a motor fails to run from mechanical trouble, either in the motor or the instrument it operates. The device is particularly

of service, first, in synchronizing demand readings from two or more installations too widely separated to register on one demand instrument, as considerable difficulty is experienced in regulating spring-driven clocks with sufficient accuracy; second, it enables extending the period of visit to the meters from the usual seven-day period to a fourteen-day period or longer if desired.

Company No. 4. This company is not using the master clock feature of the Warren system at its central station, but is experimenting with the small timing elements in time switches for street lighting, timing elements for maximum demand indicators and timing elements in three types of graphic recording voltmeters and wattmeters. The experience to date, which has been limited to a small number of devices, has been very satisfactory.

TYPE M-6 DEMAND METER (GENERAL ELECTRIC COMPANY)

A new demand meter with a self-winding clock has been designed to take the place of the present type M-5 demand meter which contains a spring-driven 8-day clock movement. The gen-

Fig. 2—Type M-6 Demand Meter, Cover Removed

eral appearance of the device will remain the same (Fig. 2), the principal change consisting of substituting for the spring-wound clock an electrically driven clock movement which consists of a

small direct current motor geared to the main spring shaft of a clock movement. The small motor is arranged to be connected direct to the proper supply voltage and maintains a constant tension on the main spring, thereby giving a constant rate to the movement.

As shown in the illustration, the commutator and brushes are mounted at the front of the device to permit easy inspection and cleaning. A ratchet and pawl are provided on the spring drum to prevent backward rotation in case of voltage failure, the spring being capable of running the clock for about one hour after the voltage has been cut off.

While mention is made of this new development, the meters will not be ready for delivery for about six months.

TYPE H-2 DEMAND METER (GENERAL ELECTRIC COMPANY)

The Report of the Meter Committee for 1915 described the type H demand meter, which is a thermal current indicator. The original device, as described in the 1915 report, has been redesigned in order to improve the operation and to eliminate trouble encountered in obtaining perfect temperature compensation.

The new design, known as Type H-2, is shown in Fig. 3 and Fig. 4. It will be noted that in place of the two spirals of thermostatic metal originally used, the construction now consists of two flat strips of thermostatic metal, one attached to the heating element and the other acting as a compensating element for tak-

FIG. 3—TYPE H-2 DEMAND METER, COVER REMOVED

Fig. 4—Type H-2 Demand Meter, View From Bottom

ing care of temperature changes common to both elements. The characteristic curve of the device is the same as shown in the original report.

A NEW SYSTEM OF METER READING

A new system of meter reading which has some novel features and which may be of interest to member companies, has recently been adopted by the Hartford (Conn.) Electric Light Company.

The weaknesses of the commonly used systems were considered individually and an effort made to correct them; such as eliminating estimated readings, preserving meter reading records from loss and mutilation, avoiding delay in revision of meter reading sheets due to their absence for either reading or bookkeeping purposes, and furnishing a record of the time at which meters are read—thus putting the readers' movements under definite control.

By this system, the Company is able to keep all its vital records centralized in its own building under the care of competent employees, the meter reader having access only to a printed copy of the necessary records—which may be duplicated in less than one minute.

The following is a brief description of the essential features of the system and its operation:

Original records of meters with names of consumers, locations and other information of value to the readers, are kept in the form of permanent, indestructible plates which can be used in some form of printing machine such as the addressograph. These plates constitute primary records and are never removed

from the direct control of the reading department. At any time they can be changed in such manner as conditions require. They are filed in groups representing reading trips.

On the day before a trip is to be read, the address plates for the trip are run through the automatic addressing machine and the impressions printed, properly spaced, on a continuous strip of paper approximately four inches wide, the average length being twenty feet. The plates are then returned to the file. The reading strip is wound on drums and sealed into a small metal box resembling a film camera (see Fig. 5 and Fig. 6). Two small cranks make it possible to bring any portion of the strip into view through an opening in the box. In this way, any meter record printed on the strip may be brought into view and the reading entered. As no previous readings are furnished the

Fig. 5—Indexing Device

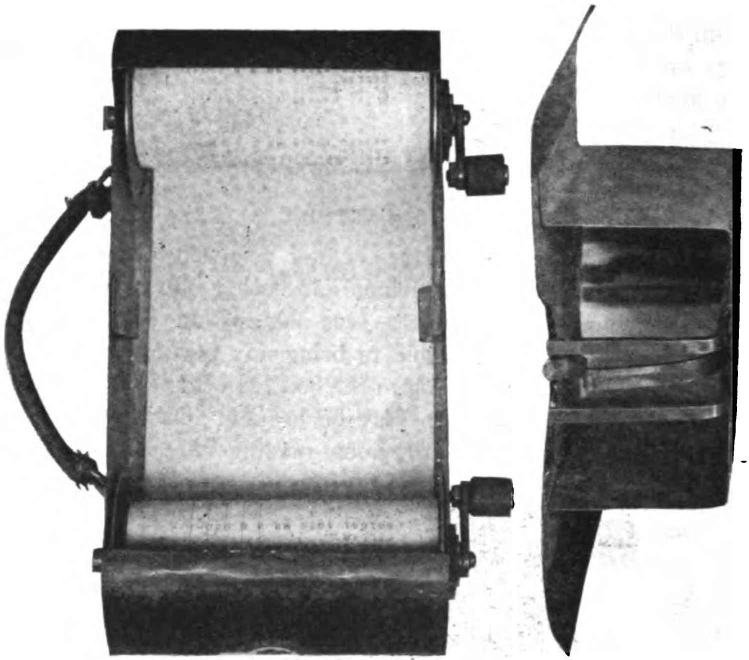

FIG. 6—INDEXING DEVICE OPEN

reader, he must actually visit the meter itself and deception is impossible.

In the box under the paper strip is a time-recording mechanism which automatically makes an identifying record of the time at which the reading is made.

After the completion of the reading trip, the strip may be used and filed by the accounting and bookkeeping departments without delaying or complicating any other work.

PORTABLE LAMP AND SCALE GALVANOMETER
(The Leeds & Northrup Company)

A recent development is a compact portable galvanometer, simple and rugged in its construction and completely self-contained with a lamp and scale. It is most convenient to use and less tiring upon the operator than either a pointer or telescope scale galvanometer. It is well adapted to shop Wheatstone Bridge or Kelvin Bridge measurements, or for any other purpose where a sensitivity of 20 megohms is sufficient and where a large

number of measurements are to be made. In addition to its ease of reading and comparatively high sensitivity for a portable instrument, it is quick in its action, having a period of about 4 seconds. The instrument is quite rugged in its construction and will withstand as much rough usage as an ordinary voltmeter.

By purchasing an extra system, the instrument may be adapted for both microvolt and microampere work.

The general appearance of the instrument and its scale is

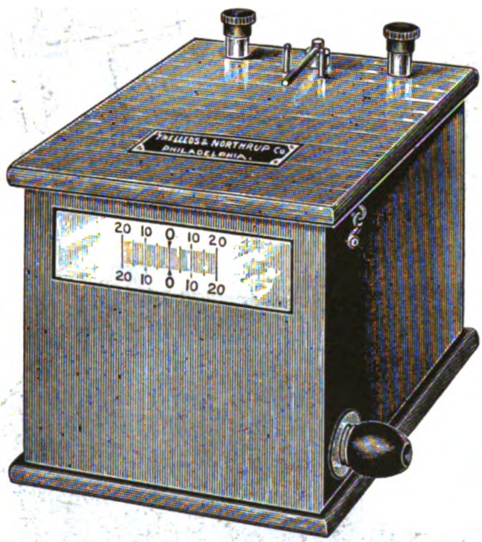

FIG. 7—PORTABLE LAMP AND SCALE GALVANOMETER

shown in Fig. 7. The box is made of hard wood and measures approximately 8½ in. by 5½ in. by 5½ in. The total weight of the instrument is about 5½ pounds. Suitable provision is made for conveniently replacing and focusing lamps when necessary. A rod is provided on the top of the case by which the zero of the galvanometer may be adjusted. A convenient connector is provided for attaching the lamp to a four-volt circuit.

The scale is black on a translucent background. It is regularly furnished with zero in the center, but is furnished with zero at one end if so desired.

The optical system will be understood from an inspection of Fig. 8.

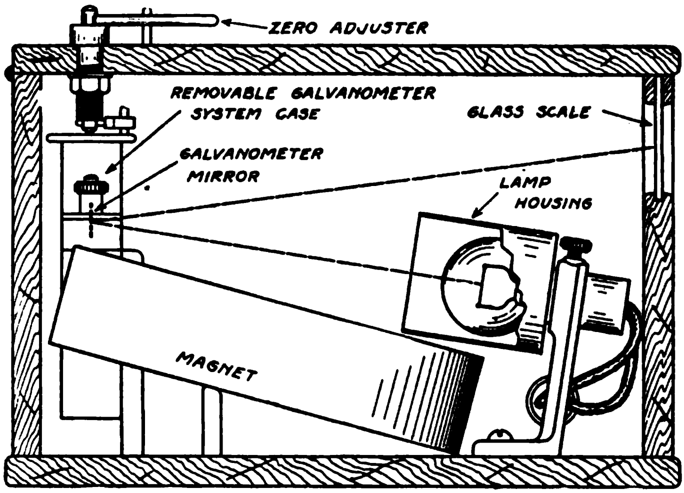

FIG. 8—CROSS SECTION OF GALVANOMETER

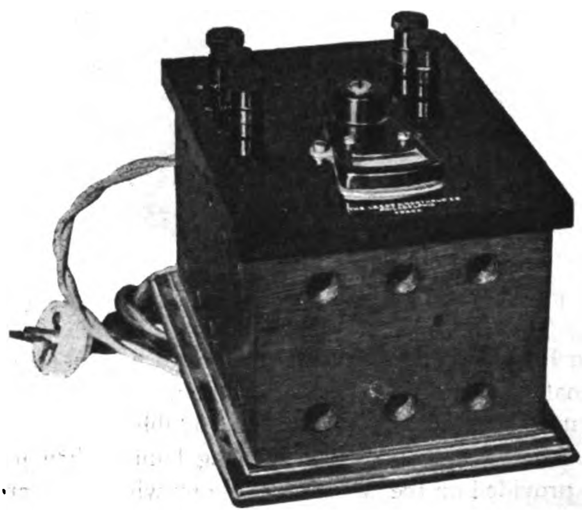

FIG. 9—A. C. GALVANOMETER

The lamp provided with this instrument has a single straight filament of high intrinsic brilliancy. It operates on 4 volts and requires a current of 0.5 amperes. It may be operated either from a storage battery or from an ordinary lighting circuit. If run from a lighting circuit, a lamp of proper capacity or fixed

resistance must be put in series with the small lamp. The manufacturers furnish such resistances, if desired.

The galvanometer system is equipped with a concave mirror. By a small movement of the lamp, the image of the lamp filament may be focused on the translucent scale. When the lamp has once been focused, it should require no further attention during its life.

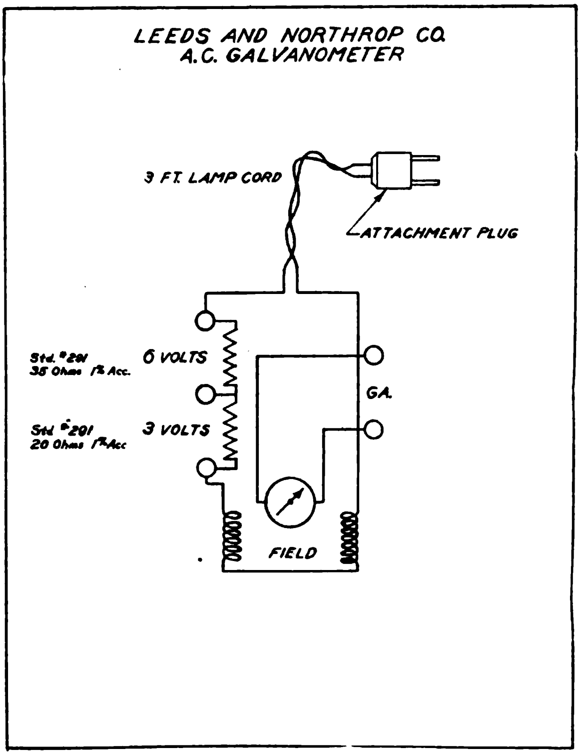

FIG. 10—DIAGRAM OF CONNECTIONS

The galvanometer coil is suspended and not supported with pivots and jewels as in the ordinary type of portable galvanometer.

The moving system of this galvanometer is mounted in a small metal case and is removable, so that if trouble occurs in the moving system it involves only the lifting out of this moving system and its return to the manufacturers for repair, a simple

and inexpensive process as compared with the return of the entire galvanometer required by other types.

A. C. GALVANOMETER
(The Leeds & Northrup Company)

The alternating current galvanometer is for use on a 60-cycle, 110-volt circuit, the field being separately excited. The working current for the bridge or other network upon which the test is being made is supplied from taps to a non-inductive resistance in series with the field winding. The current in the working circuit is therefore in phase with the field current and the moving coil of the galvanometer is connected to the network as the detector.

Fig. 9 shows the general appearance of the instrument and Fig. 10 shows the diagram of connections.

Respectfully submitted,

F V MAGALHAES, *Chairman*
A S ALBRIGHT
R M BOYKIN
F H CHAMBERLAIN
J S CRUIKSHANK
B CURRIER
C G DURFEE
WM EICHERT
C P GARMAN
F R HEALY
C H INGALLS
C J KELLAM
OTTO A KNOPP
M H PITTMAN
C O POOLE
C J THELEEN
A G TURNBULL
WM VOLKMAN
W L WADSWORTH

THE CHAIRMAN: We will now proceed to the discussion of the various portions of this report and I will ask Mr. W. L. Wadsworth of Minneapolis to discuss the portion on Educational Courses.

MR. WADSWORTH: The Sub-Committee on Educational Courses, of which I am Chairman, sent out letters to 100 different companies, and received in return ten different courses. Fifty of the companies stated that they had no definite course for their meter men. The necessity of some definite course or method of instruction to train meter men was emphasized during the war. As this is a new field of thought advanced by the Meter Committee, the Committee asks that these questions be discussed very fully so that we may outline a course or courses which will be suitable for the majority.

W. H. FELLOWS, Washington, D. C.: Early in the war we realized the necessity of some training for the meter men, and while we have not a large force of them in Washington, we picked out some four or five to break in as testers. Our force was almost totally depleted by the draft, but I was fortunate in being able to keep one man with meter experience and testing ability. As he was acquainted with this subject, he was put into the shop, and soon he could turn out men who were able to go out and test meters. Some of them could test either direct or alternating current meters of small capacity only. A few of those whom we trained have remained with us and have broadened out, while some of them have gone into other fields.

GEORGE E. SNIDER, Toledo, Ohio: It is very gratifying indeed to learn that the Committee has taken up this question. We have been attempting to outline a course for training men for meter testers, and it has proved to be quite a problem. We have finally settled on a course which we will soon start; it is based on our experience of the past year.

At the beginning of the war we lost fifty per cent of our testers and it became necessary to train men at once and train them quickly. We have found that by giving them close personal instruction and watching them very carefully they have shown much better results than they did by our former method,

which was to let them start through the department, working as helpers, etc.

I think there is a decided need for such a course as the Committee has outlined for both the large and the smaller companies. It is comparatively easy to train meter men in the larger companies, but it is a difficult proposition in the smaller companies having only four or five men.

If such a course covering practical meter work could be furnished by this Committee, I believe it would be greatly in demand. I know of many instances where we have received inquiries from various men as to what is available in the way of literature and text books on meter work. When we investigated the field we did not find much outside of the Metermen's Handbook and Jansky's Electrical Meter. Therefore, there is little opportunty at present for the self education of meter testers, and I believe all of us, particularly in the larger companies, must adopt some carefully considered course of training for our men. These men at the end of the year show remarkable progress when given this instruction.

It is our intention in the Toledo Railways and Light Company to appoint a regular instructor to supervise the work of these students as they pass through the various divisions of meter work. Specified reading courses will be given them and they will also receive lectures and will be allowed time for the asking and answering of questions pertaining to their work. It is hoped that in this way we will be able to eliminate early in the course those men who will not make successful meter testers. In several instances we have carried men in our department for from one to two years and then found it necessary to transfer them to other classes of work, as they were not at all adapted to meter work. By the quick elimination of such men you not only save time and money of the company but also that of the man under consideration.

Warren Partridge, Clearfield, Pa.: There is one subject I would like to recommend to next year's Meter Committee, and that is, the question of a two-rate meter. Many companies are facing a load situation never dreamed of a few years ago. For example in the coal mine districts we have a day-peak

two to three times as great as our lighting peak at night, and between four in the afternoon and seven in the morning current could be sold at a very low rate. I think a two-rate meter would offer inducements quite apparent to the customer for buying off-peak current, inducements which are not so obvious on a regular demand rate.

JOHN J. REILLY, Philadelphia: I am exceedingly interested in the meterman's training course. We have had considerable experience with such a course, due to the fact that during the war 65 per cent of our men were in service. We then had the difficulty of continuing our work and found it necessary to establish a course for training meter men to take the place of those who had gone. We used a course which is outlined in the report as Course No. 3. New men were employed with certain requirements as to age and education and were placed on the practical work on the line, and in connection with that work three times a week for an hour each time the men were given instructions under experienced foremen and competent instructors. The different types of alternating current meters were available for them and they were perfected in the testing and adjusting of these types. During this course, which covered three months from the time it was put in operation, the men were given intensive training and frequent examinations. They were also told that certain results were expected of them, and those who could not size up at the end of a certain period were eliminated. The subject matter of the examinations was covered in talks and lectures. An average of 70 per cent was required and the men who did not make it were dropped from the course and in some cases dropped from the employ of the department. As a result ten men satisfactorily passed the final examinations, since which time they have been out on the line and have continually increased in their daily average of work done. This average compares very favorably with the older men's work and averages. I would advocate that the Meter Committee lend its approval to some specified course, and I believe satisfactory results can be achieved.

In regard to the course established by the State College of Iowa, I am of the opinion that the time given to it is too short

and that conditions on the line are different from those which the men experience in the laboratory and shop and cannot be duplicated therein. With the experimental boards that we use and our course I feel sure that with a class of 15 or 20 men inside of three months you can turn out 75 per cent of them as competent meter men on alternating current. At the end of six or nine months a special course can be given on direct current meters.

C. P. GARMAN, Dayton: I make a motion that we take the questions on Page 432 and go through the subject systematically.

F. V. MAGALHAES: This Committee sent out its questionnaire, to which it has received replies, but the Committee has not drawn conclusions. Mr. Wadsworth, do you think time would be gained by an individual vote on these questions?

W. L. WADSWORTH: I think we get more meat out of it in this way, as we have the returns from 50 odd companies.

MR. GARMAN: I withdraw the motion.

A Member from New Jersey: I would ask the Committee if it intends to develop such a course, so that it will be applicable to small companies. I find that small companies, without a regular meter tester, are more up against this problem than the larger companies, as the larger companies have two or three men familiar with meters. The smaller companies are confronted with the problem of testing 100 or 200 meters, and then they have no further use for that man for such work. If a company were organized to do testing for small companies, it would bring us great relief.

THE CHAIRMAN: Any other questions, or comments, or experiences?

W. B. HARTSHORNE, Hackensack N. J.: It might be of benefit to the meeting to explain our experience with women meter testers during the period of the war. In my particular territory we were in need of testers, and we took on two women. They were trained under the supervision of the local meter chief and got along very well at first. In the beginning they had to go out together,

owing to the weight of the apparatus to be carried and their diffidence in going into cellars alone. After a few weeks they tested about five meters a day, and then were separated. About a month ago, one handed in her resignation on the ground that the work was too hard. Last Saturday, the meter chief advised of the other woman's resignation on the same grounds, so we have finished one experience with women meter testers.

THE CHAIRMAN: One company I knew of had women testers, but they brought the meters in and had them tested in the laboratories.

JOHN J. REILLY, Philadelphia: The Public Service Commission of Pennsylvania would not allow the use of women in outside districts, but they could work in the laboratories.

THE CHAIRMAN: Do you use women testers in the laboratories?

S. G. RHODES: The New York Edison Company employs approximately fifteen women testers, their employment being confined to the company laboratory. Their remuneration is the same as that for men for the same grade of employment. The women as laboratory testers give satisfactory service.

F. V. MAGALHAES: The member from New Jersey states that the smaller companies do not have a course of instruction as they have but one or two meter testers. The reason is probably that their testers are taken from the larger companies, where they have both trained testers and courses of instruction.

OTTO A. KNOPP, San Francisco:* The need for such a course exists also in our company, although its application is more difficult and probably less beneficial in our company whose activities are scattered over large territory than it would be in a company that has all the meter work concentrated in one large city.

The older and more experienced testers should do the instructing but their selection should be based on the ability to instruct. The course should be on company's time as lower wages are given to new men in consideration of the extra expense

* Written discussion submitted by member not attending convention.

of breaking them in. If only a few men are examined, the examination should be oral, but if a large number, a written examination would be better. For men of higher education, training should be universal. For men of only Grammar School education, training should be for only certain positions.

We think it best to send new men out with experienced testers for a short time to get acquainted with the outside testing.

H. A. Howery, Kansas City, Mo.:* There is an urgent need I believe, and especially in our Western cities, for a training course for meter testers as outlined. I believe this course should be under the supervision of an instructor in preference to instructions from older and more experienced men, more especially where the course is just being adopted, in order that all interpretation and explanation might be imparted to the man with the highest degree of accuracy, so that the policies of any local companies may be inculcated in the mind of the meter testers until such time as they have graduated from such a course with a degree of reliability which would be in keeping with the responsibility placed on them—that of training new meter testers.

The writer's experience has been that the meter men give better results and better attention by means of a special instructor than if gaining their training under various meter men. I believe this is due to the fact that they receive more accurate instruction from a single source and it can be more forcibly impressed upon their minds in this form of teaching.

The writer believes that the better procedure for training a meter man is to give him his first experience in the meter shop in order to determine to what degree his mechanical ability can be relied upon for making the mechanical adjustments to the meter without damaging the instrument in any way. He should be shown the intricate operations that take place when the various appliances for adjustment are moved in one direction or the other. This should be so thoroughly explained that the student might draw a mental picture of the motions of the adjusting apparatus when adjustments are being made.

*Written discussion submitted by member not attending convention.

He should then be given a course of testing in the shop in order to teach him what effects the various adjustments have on a meter, also to what degree the adjustments effect the meter.

I believe he should then be required to pass an examination on this much of his training before he is placed on the consumers' premises for final instruction, as it is on the consumers' premises that the meter man is able to do the most good or the most damage to the central station company.

Whether the course should be on the company's time, the employee's time, or the company and employee share equally in giving their time for instruction would depend upon the local conditions in the various companies. I believe a good arrangement for this would be the proper installation of apparatus for a school conducted by the company after working hours in such a manner that the good, loyal, well meaning, conscientious and industrious employee could see so plainly that it was to his advantage to attend the school that he would not miss the opportunity, even though he had to give his own time for it.

All examinations should be written. Written answers to questions and written reports on investigations I believe to be of primary importance in the training of meter men, for ofttimes when it is necessary for a meter man to go on record with a report, he has a laborious task before him.

I believe that the training should be universal for any position in the meter department. However, I also believe it should be in graduated steps which would enable the central station manager to use his men in any position he desires, also deriving better executives for other departments in the company of which they are members. I have often seen it demonstrated that good rounded-out, thoroughly trained meter men possessing the ability to write letters and being able to explain themselves in the various problems of meter work, have made very good executives in other departments.

I believe rivalry and competition among meter men to be a good thing if not carried on too long so that the men become antagonistic toward each other. This practice, however, would have to be judged by the men being handled and the local conditions surrounding their employment.

The "Meterman's Hand Book" is loaned to the employees

in the meter department of our company, although quite a number of our men have copies which they have purchased for their own use.

The young man with a high school education is by far the best subject for employing and training as a meter man. Of course there are exceptions to this rule. The writer has seen a good many good meter men developed from ward school students, men who were addicted to home study, especially along engineering lines, but these men were rather more of an exception than the rule.

Our company has an instruction course in the form of a book which comprises most of the subjects of study as outlined in Course No. 1 in the literature you have handed me, yet it is a more general course and does not go into detail on the subdivided subjects as outlined in Course No. 1. We have experienced a great deal of trouble in keeping this book up to date due to the fact that it was made up in loose leaf form of typewritten sheets, which form does not stand the wear and tear to which it is subjected.

Little has been done along this line during the war, as the Army completely stripped us of practically all our meter men during 1917, and we are just beginning to get a few of our old men back.

THE CHAIRMAN: The next topic is "Instrument Transformers," which will be abstracted by Mr. Magalhaes.

(F. V. Magalhaes abstracts the Report of the Sub-Committee on Instrument Transformers, Test Practice and Performance.)

THE CHAIRMAN: The question is now open for general discussion.

F. J. MURMANN, Westchester Lighting Co.: A great many member companies are now paying a lot of attention to slight inaccuracies and do not pay much attention to the instrument itself.

W. H. FELLOWS, Washington, D. C.: I want to say that the instrument transformer is an important piece of apparatus. It is generally connected with an installation of considerable mag-

nitude as to kilowatts, and considerable income is derived from such customers. In Washington we have used the two rotating standard method of testing instrument transformers, which was developed by the Bureau of Standards. We find it long and cumbersome, and we are in search of shorter methods. I think the Meter Company can do nothing better than to place in the hands of the member companies a shorter method, and to determine whether it is best to test instrument transformers on the consumer's premises or bring them into the shop. We are working under a five year period, and it is not yet five years since we first began making tests and filing the records in such a manner that we can refer back to them.

I was a little surprised at the inaccuracy figure in transformers, due to overload. I think a little research might be made to determine whether such inaccuracies can occur, and then be automatically corrected by gradually tapering off the load from the heavy overload. I would like to be informed on the subject.

In conclusion, I wish to state that I know the Meter Committee has done considerable work on these lines, and I think this work should be followed to its logical conclusion. I know the Committee will do that, as it is a hard-working committee, and I want to congratulate it on what it has done this year, especially as the time was so short.

J. B. Gibbs, Pittsburgh, Pa.: The accuracy of instrument transformers has a direct bearing on the revenue of the central station, and it is important to know how much the accuracy will change after a few years' operation. The only factors which can change are the iron loss and the magnetizing current. In very old transformers, aging may affect these factors, but no evidence of aging has been found in the silicon steel which has been used in first class transformers for the past ten or twelve years. The Committee's report shows that the magnetic history of the transformer affects its accuracy, and this seems to be the principal cause of changes in accuracy in good modern transformers. In voltage transformers the effect of a change in exciting current is negligible, while in current transformers it may be quite appreciable. It is, therefore, more important to check current transformers than voltage transformers.

Most of the companies which have adopted periodic testing have come to one of the secondary methods in which the transformer under test is compared with a known standard transformer. If the standard transformer is accurately calibrated, these methods are capable of very good results.

C. H. INGALLS, Boston: I wish to emphasize the importance of the results on Page 454 of the Report. These came to the attention of the Transformer Sub-Committee rather late and there was no time to make exhaustive tests, but the results indicate that the inaccuracies found in service tests may have been due to short circuits rather than aging, the cause to which they have been attributed in the past. I think the Committee intends to continue this invesigation. The tests also seem to indicate that open circuiting the secondary does not affect the ratio of the transformer as much as we have thought in the past, and this will be further investigated.

The data as a whole, compiled by the Committee, indicate that the current transformer is a very reliable part of the meter equipment, the results being consistent for each type, and that there is little deviation between the different types.

C. S. VAN DYKE, Schenectady, N. Y.: About two years ago we made tests on 84 current and potential transformers in our substation, which was thirteen years old. Some of these transformers had been tested when built by the General Electric Company, so that we had previous records for comparison. The change, if any, in the ratio or characteristics of any of the transformers, was so small that it was not sufficient to pay for a periodic test. The slight difference could be accounted for by the personal element, different methods and calibration of instruments.

It is our conclusion that to check the ratio of the transformer at one or two points, and then compare these results with the characteristic curves of the type of transformer, shaping the curve to the points, gives a very good idea of the accuracy without going to the extreme trouble of making full and complete tests.

The only likelihood of the transformers becoming commercially inaccurate is through mechanical injury, or burning out,

both causing the insulation between turns to drop. This, we think, will show itself in some way before being detected by periodic tests, and so the periodic test is of very doubtful value —except the initial one.

A Member*: In our Company we believed the difficulty of broken down insulation on transformers was due to release, and we lifted the secondary in shunt with the meter, and took one reading. Then if there was a breakdown, most of the current would go through the secondary, and the meter would be very inaccurate. If it showed only a slight inaccuracy it would indicate the transformer did not have a short-circuit.

H. J. Blakeslee, Hartford, Conn.: The Hartford Electric Light Company has used secondary methods in testing current transformers for several years. At present, the two watthour meter method is employed. We have been very particular to use as a comparison or reference transformer one which has been standardized with a secondary load consisting of the same meter elements as are to be used with the transformer under test when put into service. This has brought up a question as to whether in some of the primary methods of testing instrument transformers, an error is not introduced owing to the secondary load being different from that which will be used in service.

We constructed an instrument for this work, using two Sangamo 5 ampere meter elements and having a convenient switching arrangement for interchanging the meter elements. The time required for making a test by this method is rather excessive at light load points. Efforts to lessen the time required, by using watthour meters of smaller current rating, are misdirected as an error is thereby introduced due to change in the character of secondary load.

In order to obtain a set of curves for our comparison current transformer, we wound an auxiliary primary coil upon its core, making the nominal ratio one to one, and then used our watthour meters, one on the primary and one on the secondary of the transformer. By taking readings at many load points and letting the meters run for a large number of revolutions, we obtained registration curves of great accuracy.

* Unable to ascertain name and company connection of speaker. Tech.

The report of the Meter Committee points out the impossibility of setting a meter so that in connection with its transformers it will have a registration of 100 per cent through its entire load range. For this reason it does not appear that transformer phase angle curves are of particular value in ordinary meter practice. If transformer connection factors for three or four points are known and intelligently used, the resultant overall accuracy can be made sufficiently close.

OTTO A. KNOPP,* San Francisco, Cal.: In our company it has also become the practice not to fuse potential transformers in polyphase meter installation, but this practice has many objections. It has been found that potential transformers will get damaged, introducing large errors in registration while staying on the line due to lack of fuses. To overcome this, it is planned to install a simple little device in connection with fuses which will stop the meters in case only one of the fuses blows.

In our company we have been using a testing equipment to test current transformers on consumer's premises, but this was abandoned several years ago as errors found in the transformers in service were of rather small order. The writer's "two watthour meter method" was used as described in the N.E.L.A. *Bulletin* of November, 1916. The consumer's meter was used as one meter of the two watthour meter method.

THE CHAIRMAN: We will now take up the question of the Warren Time Element, and I will ask Mr. C. H. Ingalls to present that subject. This item promises to be very interesting and is of much wider application than most of our rules.

C. H. INGALLS, Boston: I think that meter men who have had occasion to use time elements, particularly in demand work, have realized the difficulty in obtaining a device that will keep time and do the work required by the demand feature which imposes a heavy duty on the clock. The time element is usually a double spring clock or a specially made movement, and it is necessary to inspect it at intervals of from one to seven days. Even with these frequent inspections there is considerable difficulty in keeping the clocks accurate. A summary of the results

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* Written discussion submitted by member not attending convention.

obtained from spring-driven clocks shows that 65 per cent are accurate to 5 minutes a week and 4 per cent will be found stopped.

The Warren clock is a synchronous motor, the speed of which is dependent on the frequency of the circuit and is fully described in the report. This clock allows us to operate a device for practically any length of time without frequent visits and has plenty of power to drive any of the ordinary instruments, with a splendid margin of safety. Demands may be synchronized from two or more places, since with the Warren clock, even if the frequency is a little off, all the clocks will run at exactly the same rate.

Another advantage of this clock is its continuous uniform motion, for which reason it may be readily adapted for measuring short time intervals in place of a stop watch. We have very few practical devices for this purpose, depending mostly on stop watches or a vibrating mechanism. With a watch we are unable to get an accuracy better than 1/5 of a second, the usual time for one swing of the balance wheel. By a suitable attachment to a device of the Warren motor type, which rotates at a continuous uniform speed, measurements may be made to 1-200 of a second. Such an arrangement is small enough to be readily portable.

Another advantage of this motor is the matter of repairs. An ordinary clock should be cleaned at least once a year or a year and a half, which usually means that the whole instrument will have to be brought back to the central station and undergo thorough cleaning. The Warren motor is small and one motor may be easily substituted for another on the system. It may be interesting to compare results obtained from 200 spring clocks and those from 70 Warren motors. Based on 2700 "clock weeks" for the spring-wound clocks, 35 per cent were in error more than 5 minutes per week. Only 10 per cent of the Warren clocks were in error, and the majority of these errors were due to opening the service switch for repairs on the installation, no provision having been made to connect the Warren motor back of the service switch.

The Chairman: Mr. Warren, will you sketch briefly the possibilities of the commercial applications of these devices?

H. E. Warren, Ashland, Mass.: If any of you had been asked two or three years ago about the feasibility of controlling the frequency of the alternating current with sufficient accuracy to run a clock, you would all have been ready to deny the possibility, but the clock on the wall there (indicating) shows what is being accomplished by the Atlantic City Power Company. There is a device at the central station so that at any lamp socket one of these motor-driven clocks can be connected and give the same time as you have here. Any of you who wish to can see the apparatus in operation at the booth in the main hall on the pier. I have here in my hands one of the little motors, so you can get an idea of the size, shape and compactness of it. This has an output of about one-millionth of a horse-power, but the fact is a one-millionth of a horsepower is large as compared with an ordinary clock movement. The clock movements actually used do not have nearly so much. The power required to drive the hands of the clock on the wall there measures one one-billionth of a horsepower. The power in this motor is sufficient to drive any recording instrument or even to tear the paper or to slip one of the gears on its shaft if the normal feed is prevented.

These motors can be used in all places where an ordinary spring-wound clock can be used. Connection with existing mechanism can often be facilitated by the use of a small flexible coupling. The various regular demand indicators have been provided for, and, if you wish to, you can examine the movements on exhibition, designed to fit in place of existing movements. In future you can buy equipments, fitted with these motors, for practically the prices of those instruments driven by the spring clocks.

The principal advantage of the method is that the cost of maintenance is reduced to a minimum compared with that of a spring-wound clock. That saving is so great that the expense of the apparatus necessary to regulate the system is very soon absorbed, wherever there is a considerable number of these instruments in service. The method of regulating is no longer an experiment, for we have a record of nearly three years in which it has been in use on the Boston Edison system, and the first motor installed two years ago last October is still running, and

has been running twenty-four hours a day without the slightest inspection. It has run 3600 revolutions per minute during that time, so a good many turns have been made.

F. J. MURMANN, Mount Vernon, N. Y.: I was about to ask a question to bring out discussion: What would happen to a system of this kind in an outlying district where you had 150 of these, and the line came down?

THE CHAIRMAN: Do you mean your clock system or your meter system.

MR. MURMANN: I mean an outlying system with these clocks if the time should be in error.

MR. WARREN: Of course, while the current was interrupted the motors would stop. No record would be made during that interval, and inasmuch as no current would be consumed, there would be no error in that device.

There are two types of clocks made, one in which an auxiliary movement is made to keep the hands moving and the other in which an indicator appears when an interruption occurs so that it will be reset. On well built systems the loss of time or of errors, due to the stoppage of the motors, is small in comparison with present devices.

These are instruments of precision. The motors will run synchronous with the big clock at the station house; and that will run within a few seconds a week, so that compared with the ordinary balance wheel movement, you can tolerate some interruptions.

S. G. RHODES, New York City: In order to bring out the point Mr. Warren has made, I understood Mr. Warren to show what the motor would do. He did not advocate the selling of time service, is that correct?

MR. WARREN: That is correct.

MR. RHODES: You fear, Mr. Murmann, that we would have a criticism from the customers to whom we were selling time?

MR. MURMANN: You would have several hundred instruments that would be so much inaccurate in time at the one instant.

THE CHAIRMAN: Suppose that they are on street or sign lighting? Suppose they are all turned on and off, all the lights at a given time, and you have an interruption of half an hour, what would be the situation then?

MR. WARREN: The clocks will stop during the interruption unless an auxiliary is applied to keep the hands moving.

THE CHAIRMAN: Is the man having it in his premises made to reset it?

MR. RHODES: There is no doubt of the value of the Warren Time Device, when applied to the type of device we are speaking of and for the service we are speaking about, that is, as a substitute for spring-wound clocks in use in combination with graphic meters, demand meters or time switches. If we were to sell time through the clock as on the wall it might possibly embarrass a company as the frequency of a system is accepted to be correct when within 5 per cent plus or minus and also any interruption of the service at any point makes for an incorrect timing device.

THE CHAIRMAN: The point that appeals to me is that through this method you keep better frequency on yourself, particularly in the weaving establishments and the cotton mills of the South. It seems to have its greatest gain for the power companies through that method. How much more accurate can frequency be kept by this method?

MR. WARREN: One per cent error would represent 14½ minutes a day, and it is easy to hold the error down to 1-100th of 1 per cent on the average.

MR. MURMANN: How would this stand up under short circuit conditions?

MR. WARREN: The motor will run to synchronism at 15 per cent of normal voltage and at 150 per cent. It is not injured by a momentary over-voltage of 1000 per cent.

W. J. MOWBRAY, Providence, R. I.: I would like to tell what we have done in Providence to regulate our frequency with this clock. We had a good deal of trouble in our spinning and tex-

tile mills. If our frequency ran high, the material man would say that his threads were being broken, and if it went too slow, he was getting too many pounds in. So we adopted this clock, not with the object of selling time, but with the object of regulating frequency.

Mr. Warren makes a clock, electrically controlled, which regulates closely, and we felt if we did not want to sell time, we would get out of it cheaply. We have a company in Providence that maintains a great number of clocks, and sends a man each week to regulate them. We had one of these clocks in the bookkeeper's office which I had moved up to the switchboard, and put alongside of it a Warren clock such as you see on the wall, which I purchased for $15, and the man regulating the frequency watched them. If he noticed the Warren clock was dragging behind, he would keep up on his frequency, and vice versa. In that way we are getting the same number of total turns to date, and we have not the trouble in breaking threads, or of being called up and told we are giving poor service. That is the way—put a good clock alongside your low-priced Warren clock and you are in position then to do the work. That settles the frequency problem for you.

THE CHAIRMAN: We must move on now. The next two questions we will take up jointly, "Fusing of Potential Transformers" and "The Maximum Demand." Mr. Magalhaes will abstract that portion of the Report for us.

(Mr. Magalhaes read pages 29, 30 and 31 of the advance printed report.)

MR. MURMANN: Regarding the fusing of potential transformers, it is our practice at 2200 volts to connect them direct to the line without fuses, for instruments and watthour meters.

Our next higher voltage being 13,200 volts, three phase, I would like to ask if there are any companies that have potential transformers on 13,200 volts without fuses?

J. H. STURGE, Trenton, N. J.: Whether to use fuses on potential transformers is simply a question of balance between the saving in apparatus by the fuse protection as against the loss

in revenue on account of fuse trouble. Most of our large power customers are buying service at 2400 volts and the minimum 2400 volt fuse which is used for potential transformers is rated at ¾ ampere or is designed to blow at a load approximating 2 kv-a. This fuse is used in connection with potential transformers rated at 50 to 200 volt-amperes, and obviously gives no protection against overload except possible direct short circuit. We have even found instances of fuses not blowing on secondary short circuit. Obviously, the fuse gives no real protection, but the annoyance in adjusting bills and the loss experienced on account of blown potential fuses clearly indicate that these transformers should be connected in solidly.

Others of our large power consumers are buying service at 13,200 volts, and we are serving these customers with potential transformers connected in solidly without fuses, as we found that fuse trouble was the only real trouble experienced. Some of these installations have been in service for several years with a record of no potential transformers lost.

Recent development in our own substation practice on potential transformers for relay operation and for other important apparatus of this character is tending toward the complete elimination of fuses in spite of the fact that this apparatus is in care of and subject to the direct scrutiny of a competent substation operator. We believe that the use of fuses for potential transformers generally should be discontinued.

C. A. Harrington, Youngstown, O.: Our company is using 2200 volts potential transformers without fuses.

Wm. Wadsworth, Minneapolis: We have ten installations that we meter at 13,000 volts. They have been in operation ten years without fuses, and we have had no trouble or loss of service due to leaving fuses out of these potential transformers.

W. H. Fellows, Washington, D. C.: We have both cases, and have had only one case of trouble without fuses. The transformer burned out or short circuited internally, and the lead burned off. There was no interruption of service.

J. B. Gibbs, Pittsburgh, Pa.: It seems as though there might be two questions to consider here—one is protection of the trans-

formers, and the other is protection of the system. It is practically impossible to protect a voltage transformer with fuses, but if the transformer is so located that trouble there might result in trouble in the system, then fuses might be put in to disconnect it. With large high voltage systems it is customary to use protective resistors in series with voltage transformer fuses, to limit the short circuit current.

C. J. KELLAM, Newark, N. J.: We use solid fuses in all our potential transformers, which in case of trouble may be used to disconnect the transformer from the line. These transformers may be placed either ahead of or behind the disconnecting switches, but, as it is necessary to send out and have these fuses removed where it is necessary to make any tests on the line, our rules are to connect them after the disconnecting switches.

THE CHAIRMAN: This is open now for general discussion.

H. L. WALLAU, Cleveland: When we first made the station, we used fuses of 2200 volts. The first year we found the fuses had blown twice, that is, one had blown on two different occasions, and it was rather difficult to check up just how much we lost. After we lost the second one, we decided to leave the fuse holders in, but to fasten them in. They have been installed two years now. We have not had any trouble with them. I do not see any objection to that practice.

THE CHAIRMAN: Has anyone anything to say about maximum demand?

J. C. MARTIN, Allentown, Pa.: In the matter of power factor indicators, we have found that the graphic indicators available are not accurate over a wide enough range to meet conditions. The two single-phase watthour meter method, of course, does not give accurate results on an unbalanced circuit. Contracts containing power factor clauses are not unusual, but enforcement of such clauses is decidedly unusual. This is due largely to the lack of proper instruments to obtain accurate measurements.

Two instances occurring recently indicate that as a result of this condition we are not getting the benefit of the power fac-

tor correction capacity of equipment now connected to our systems. In the first case we were experimenting and put in two single-phase watthour meters to learn what conditions existed, the customer not realizing what we were doing until the test was well under way. The improvement in the power factor conditions between the beginning and the end of the test was rather astonishing and showed what could be accomplished if a power factor clause were really enforced.

The second was in a comparatively small installation, where we discovered a rotary converter operating under the worst possible power factor conditions. The operator refused to make any changes that would improve conditions, as he had been told that if he operated his machine in any other way, he would burn it up. These instances tend to show that the development of proper methods and instruments for power factor determination is of extreme importance.

J. H. Sturge, Trenton, N. J.: I must disagree with the previous speaker as to the use of a rotary converter for power factor correction, except insofar as the power factor may be corrected by adding a unity power factor load to a load already operating at a lagging power factor, and thus bringing the power factor to some point nearer unity. A rotary converter is so constructed that if any attempt be made to operate at leading power factor, trouble with the "tap" coils will inevitably be experienced, and the length of time before this trouble is experienced will depend upon the percentage of rated load that is carried by the converter. Any attempt to operate at full direct current load with a power factor beyond the limits of 95 per cent or 96 per cent lead or lag will soon result in coil trouble, and for straight power factor correction resort must be had to static or rotary condensers. For correction of power factor with no additional mechanical load to be carried, the use of the static condenser is clearly indicated.

Mr. Fellows: The present watthour meter, especially for alternating current, has been brought to a high degee of perfection, and we are satisfied with its continued operation over long periods. This is not so with the demand meter. The demand meter needs frequent attention. The only thing I can say

to the Committee is to "keep eternally at it" until we get what we want.

W. J. Mowbray, Providence, R. I.: In Providence we found, as has been found elsewhere, that the cheap mechanism demand meters were very unsatisfactory, and the satisfactory ones very high in price, and really I have come to the conclusion that to get all you want in the way of a mechanism demand meter, you need a gaphic watt meter, and it would not be practical to install graphic watt meters on all these customers. So we use a few of them to take the place of a great number, and ship them from place to place. The man has an automobile and a comparatively small number of graphic watt meters. Of course when the meters are moved from place to place, there is an exchange of meter, and there is a question of whether you hit the maximum demand or not. You must get in on a man's peak, and to ensure getting in on that peak, we have a system. We take Mr. Smith's business, as an example: If his kilowatt hours double, his maximum demand has increased very largely. Now in the office we plot a curve of kw-hr. and that curve would look something like this (speaker illustrates curve on blackboard). This particular customer is the Cruikshank Engine Company. This card covers a period of two years and shows this kw. capacity has varied in this way for those two years. Here is nothing here (indicating on diagram) and so on. We have here (indicating) one hundred to two hundred, and so on up to one thousand.

Now, we have these cards and we know this man's business peaks are in November. The peak will nearly always come in the same month.

Last year we put in a graphic meter for one month. This curve gives us warning whether that man's demand will be larger or less than before. Here we found that one month before the peak would come, he was taking as much as he did last year in the peak. So we put in the peak. But it takes only a month and then we can take that graphic meter and use it elsewhere on customers having a peak which does not come at the same time this man's peak comes.

We have had this in operation for some time and we believe

that one man and an automobile and a few meters is all that is necessary for the work.

THE CHAIRMAN: We will now have the report of the Nominating Committee, and in the absence of Mr. Sproule, Chairman of the Committee, I will ask Mr. Magalhaes to present the report.

REPORT OF NOMINATING COMMITTEE

Your Nominating Committee has the honor to report the following nominations for officers of this Section for the ensuing year:

For Chairman, I. E. Moultrop, The Edison Electric Illuminating Company of Boston, Mass.

For Vice Chairmen, N. A. Carle, Public Service Electric Company, Newark, N. J.; A. H. Lawton, Consumers Power Company, Jackson, Michigan.

Member of Executive Committee, R. F. Schuchardt, Commonwealth Edison Company, Chicago, Illinois.

(Vacancy in Executive Committee caused by election of Mr. I. E. Moultrop as Chairman of the Section, to be filled at the first meeting of the Executive Committee.)

(Motion made, seconded and carried, that the nominations be closed, and that the Secretary cast the unanimous ballot for the gentlemen named.)

(The Secretary reported that he had cast one ballot for the gentlemen named in the Nominating Committee's Report.

THE CHAIRMAN: I declare the ticket duly elected. The hour is late and I declare the meeting adjourned.

(Session adjourned.)

REPORT OF THE SPECIAL JOINT COMMITTEE ON DETERMINATION OF POWER FACTOR IN POLYPHASE CIRCUITS

The subject of "Power Factor" has been prominent in the discussion this morning, although Mr. Dow has carefully avoided saying anything as to what constituted "Power Factor" or as to proper methods of determining it. It is to clarify the situation in regard to these points that this Special Joint Committee on Determination of Power Factor in Polyphase Circuits was established.

A number of men and organizations in recent years have given study to the power factor problem and one of the first things which develops in such a study is the fact that there is no generally accepted definition of the term "power factor" as applied to polyphase circuits, nor even as to the underlying purpose which such a definition should serve to express. This condition of uncertainty has arisen naturally from the fact that until recently there has been little practical commercial incentive to establish a universally accepted understanding as to these points.

This absence of practical incentive is due to the fact that most polyphase loads hitherto have been approximately balanced, while the differences between various possible definitions of "power factor" become of importance only in unbalanced loads. At present, however, there are increasing developments in types of industrial power loads which are attended by unbalanced conditions between the phases, unbalances as to amounts of loads and as to phase relations. In such cases the numerical factor may vary widely with different definitions.

The increasing commercial importance of this character of load and the tendency, as brought out at the discussion this morning, toward such refinements in power contracts and rates as will reflect accurately the various elements entering into the cost of service, have combined to render the problem a matter of im-

mediate practical interest. The need for an authoritative understanding has resulted in this Special Joint Committee being formed between the American Institute of Electrical Engineers and the National Electric Light Association. This does not mean that the work of the Committee will be confined to these two associations. If other bodies or associations are interested and desire to participate in the work they will be welcome.

The subject has proved more involved and complicated than would appear on the surface, and our work thus far has consisted mainly of collecting a large amount of information from various sources as to possible definitions of "power factor." The divergency of views is rather astonishing. The subject is one of international significance and this Committee will coordinate its work with that of other bodies abroad.

The Committee's aim has been set very high, and it hopes to accomplish the following results:

First—To consider the purpose to be fulfilled in the use of the term "power factor" in the commercial engineering and scientific aspects of the electrical art.

Second—To offer for the electrical industry in the United States a definition which will definitely and correctly express this purpose and will be suitable for scientific, legal and commercial use.

Third—To study, probably in conjunction with the manufacturers, the best available means of measuring the function thus defined.

The Committee may possibly offer also certain suggestions or recommendations as to methods of providing for power factor in contracts and rates.

The Committee is small and the questions involved are of wide interest. We hope that anyone who has made any particular study of the subject or has any information which will be of assistance in carrying out the Committee's program will communicate with the Committee and take part in its meetings.

The Committee was organized in February of this year and held its first working meeting on April 10th. The next meeting

will probably be held within two months. The present personnel is as follows:

R J McClelland *Chairman*
Farley Osgood *Vice-Chairman*
S G Rhodes *Secretary*
Dr P G Agnew
Frane Conrad
F P Cox
F C Holtz
Dr A E Kennelly
E W Lloyd
G A Sawin
R F Schuchardt

BY-LAWS OF THE TECHNICAL AND HYDRO-ELECTRIC SECTION OF THE NATIONAL ELECTRIC LIGHT ASSOCIATION

Amended and Adopted at Forty-first Convention, Atlantic City. N. J., June 14, 1918

Article I—Name

Section 1.—The name shall be Technical and Hydro-Electric Section of the National Electric Light Association.

Article II—Object

Section 1.—The object of the Technical and Hydro-Electric Section shall be to advance the interests of the National Electric Light Association by bringing together, into one group, those members of the Association who are technically qualified or especially interested in the theories and application of engineering principles relating to the electric light and power industry, to the end that opportunity may be given for the study of those principles and the development of the best practises in their application to the industry; to collect and disseminate useful information relating to the production, distribution and utilization of electrical energy; to promote the general adoption of the best methods and practises for attaining these ends and, in general, to consider and report upon such questions as may be assigned to it by the Executive Committee of the Association.

Article III—Status

Section 1. The Technical and Hydro-Electric Section is a National Special Section of the National Electric Light Association, organized in accordance with the provisions of Sections 1, 2, 3 and 4 of Article XVI of the Constitution of the National Electric Light Association.

Article IV—Membership

Section 1.—Membership in this Section shall be of two classes, Active and Associate.

Section 2.—Active Members shall be Class B or Class E

Members of the National Electric Light Association who shall become affiliated with the Section. Each Active Member shall be entitled to one vote and to hold office.

Section 3.—Associate Members shall be other than Class B or Class E Members of the National Electric Light Association, who shall become affiliated with the Section. They shall have all the privileges of Active Members except the right to vote and hold office. Loss of membership in the National Electric Light Association automatically cancels membership in this Section.

Section 4.—All members shall receive, in consideration of their membership, such copies of publications of the National Association and of all Section publications as shall be designated for free distribution, in the same manner as do members of other National Special Sections.

Article V—Officers

Section 1.—The officers of this Section shall be a Chairman, four Vice-Chairmen, a Secretary and a Treasurer, all of whom shall be active members of the Section. The Chairman and two Vice-Chairmen shall be elected at each annual meeting for terms of one year and two years respectively (at the annual meeting in 1918 there shall also be elected two Vice-Chairmen for terms of one year only), or shall hold office until their successors are elected. The Secretary and Treasurer, who may be one person, shall be appointed by the Executive Committee . Vacancies in any office may be filled for the remainder of the term by the Executive Committee.

Section 2.—There shall be an Executive Committee consisting of the Chairman, the two Past-Chairmen who have last held the office of Chairman, the four Vice-Chairmen, two members at large and the Chairmen of the Standing Committees, all of whom shall be active members of the Section. One member at large shall be elected at each annual meeting for a term of two years (at the annual meeting in 1918 there shall also be elected one member at large for a term of one year only), or shall hold office until his successor is elected. The Executive Committee shall be the governing body of the Section and shall have entire charge of its affairs. It shall hold meetings upon the call of the

Chairman and a majority of its membership shall constitute a quorum.

Section 3.—The Chairman shall be the Chief Executive Officer of the Section and shall represent the Section on the Executive Committee of the National Electric Light Association. He shall preside at all meetings of the Section or of its Executive Committee. The Chairman shall, with the approval of the Executive Committee of the Section, name such committees as may seem desirable and he shall appoint the members thereof. The terms of all committee members shall terminate at the same time as the term of the Chairman by whom they were appointed, unless sooner terminated by ARTICLE [illegible] Committee. In the absence or disability of the Chairman, a Vice-Chairman shall exercise the authority and perform the duties of the Chairman.

Section 4.—The Treasurer shall receive and keep safely all moneys of the Section, keep correct account of same, and pay all bills approved by the Executive Committee. He shall make a quarterly report to the Executive Committee and an annual report to be submitted at the annual meeting of the Section, and, if the Executive Committee so decides, he shall give a bond in such a sum and with such securities as the Executive Committee shall prescribe.

Section 5.—The Secretary shall keep the minutes of all the proceedings of the Section or of its Executive Committee, shall give notice of all meetings, keep a record of the membership, file reports in writing of the activities of this Section with the Secretary of the National Electric Light Association as required in Section 2, Article XVII, of the Constitution of the National Electric Light Association, and perform such other duties as may be assigned to him by the Executive Committee.

ARTICLE VI—MEETINGS

Section 1.—Regular Annual Meetings of the Section shall be held at the time and place of the National Convention of the National Electric Light Association. Special meetings may be held upon the order of the Executive Committee.

Section 2.—At all meetings of the Section ten Active Members shall constitute a quorum for the transaction of business.

Article VII—Elections

Section 1.—The Executive Committee shall appoint a Nominating Committee consisting of five Active Members, and the Chairman shall announce the names of the members so selected at the first session of the annual meeting of the Section. This Nominating Committee shall at a subsequent executive session of the Section bring in the names of those recommended by it for the offices to be filled.

Section 2.—Any active member may make nominations for any of the offices to be filled, which nominations if seconded shall be submitted for voting upon at the same time and in the same manner as those of the Nominating Committee. Whenever there are more nominees than offices to be filled, then in such cases, the election shall be decided by ballot. When there is no contest for office the Secretary may be instructed by *viva voce* vote to cast a ballot for those recommended by the Nominating Committee.

Section 3.—Voting by proxy shall not be allowed.

Article VIII—Official Organ

Section 1.—The Official Organ of the Section shall be the Monthly *Bulletin* of the National Electric Light Association.

Article IX—Parliamentary Rules

Section 1.—Robert's Rules of Order shall be the governing parliamentary law of the Section in all cases not definitely provided for by its By-Laws.

Article X—Amendments

Section 1.—Amendments to these By-Laws may be offered in writing at any meeting of the Section, and shall then be referred to a Committee to be elected by the Section which shall report at a subsequent meeting of the Section. A two-thirds vote of all Active Members present shall be necessary for their adoption, and such amendments must be approved by the Executive Committee of the National Electric Light Association.

Article XI

These By-Laws are subject to the Constitution of the National Electric Light Association, and no provision herein con-

tained or any amendment hereafter adopted shall be valid if in conflict with said Constitution or with any amendment thereto that may hereafter be adopted.

The formation of a Technical and Hydro-Electric Section of the National Electric Light Association was authorized upon the request of the required number of Class A Members of the National Electric Light Association, and the By-Laws of said Technical and Hydro-Electric Section, as above presented, were approved.

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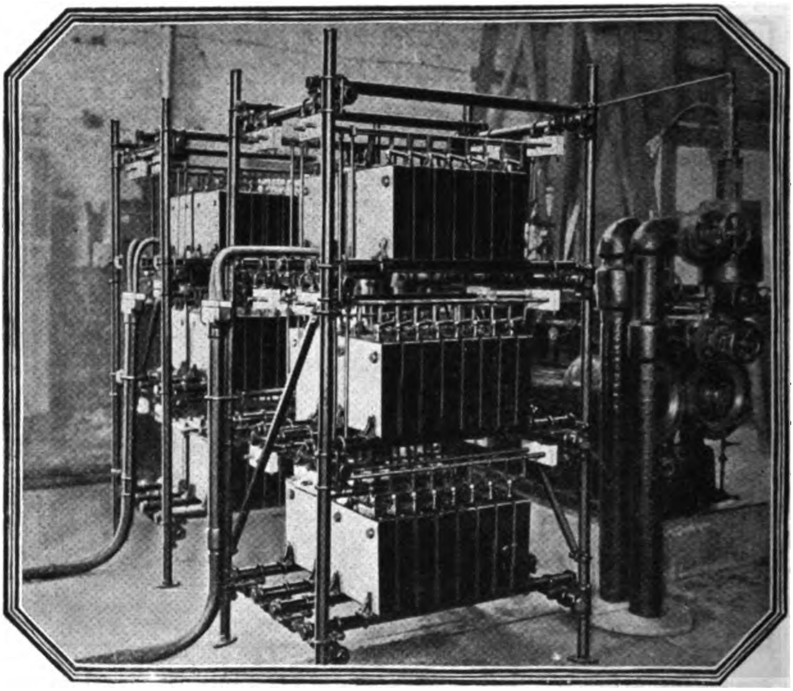

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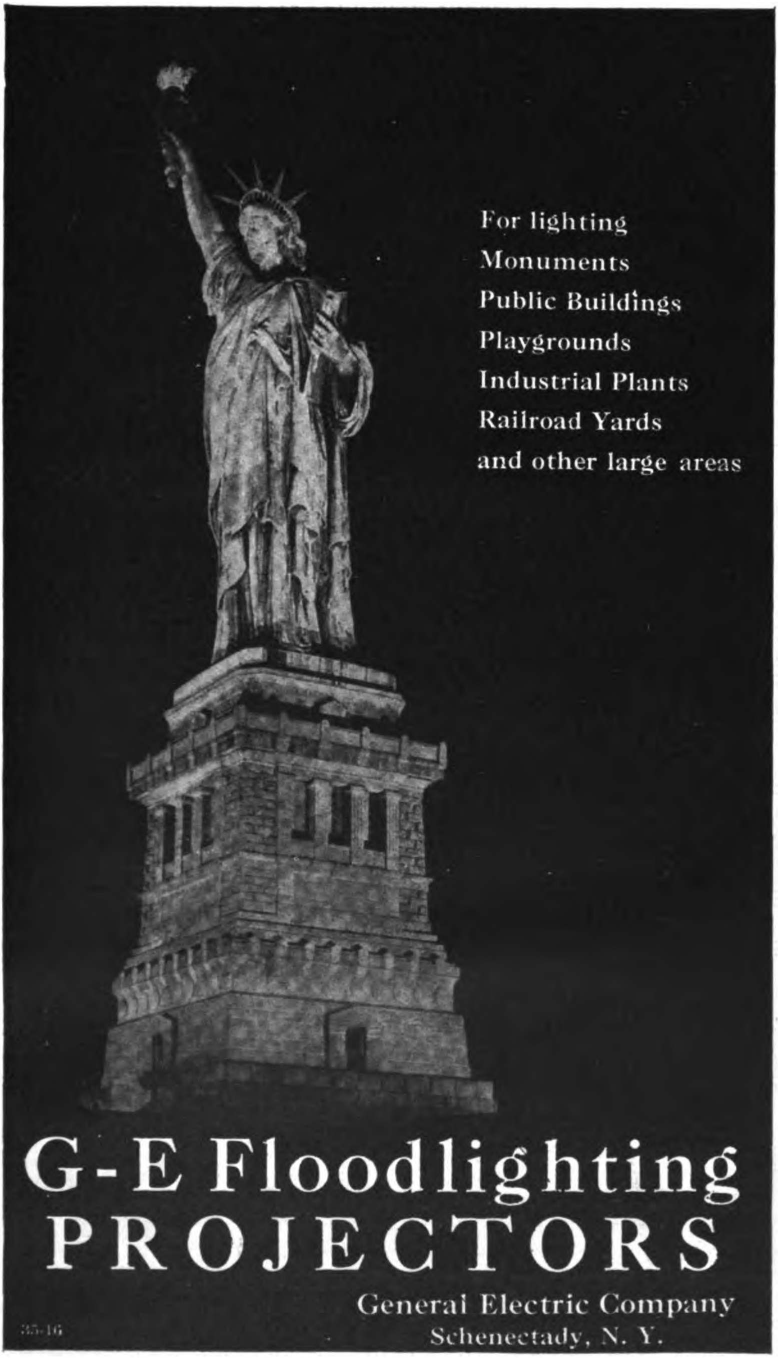
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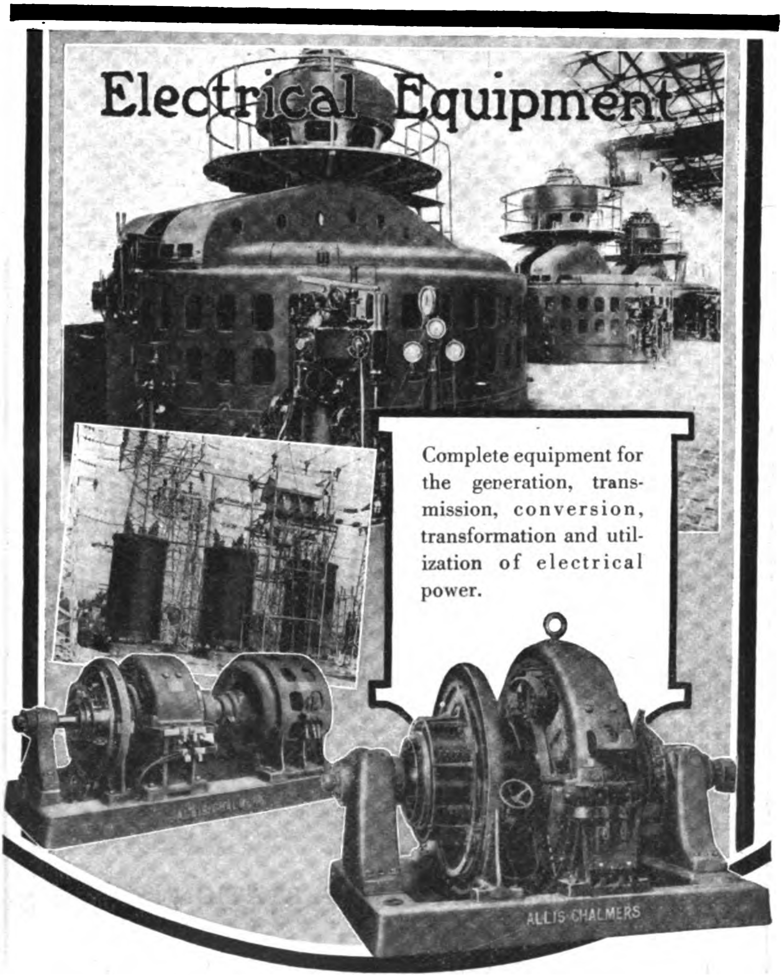
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